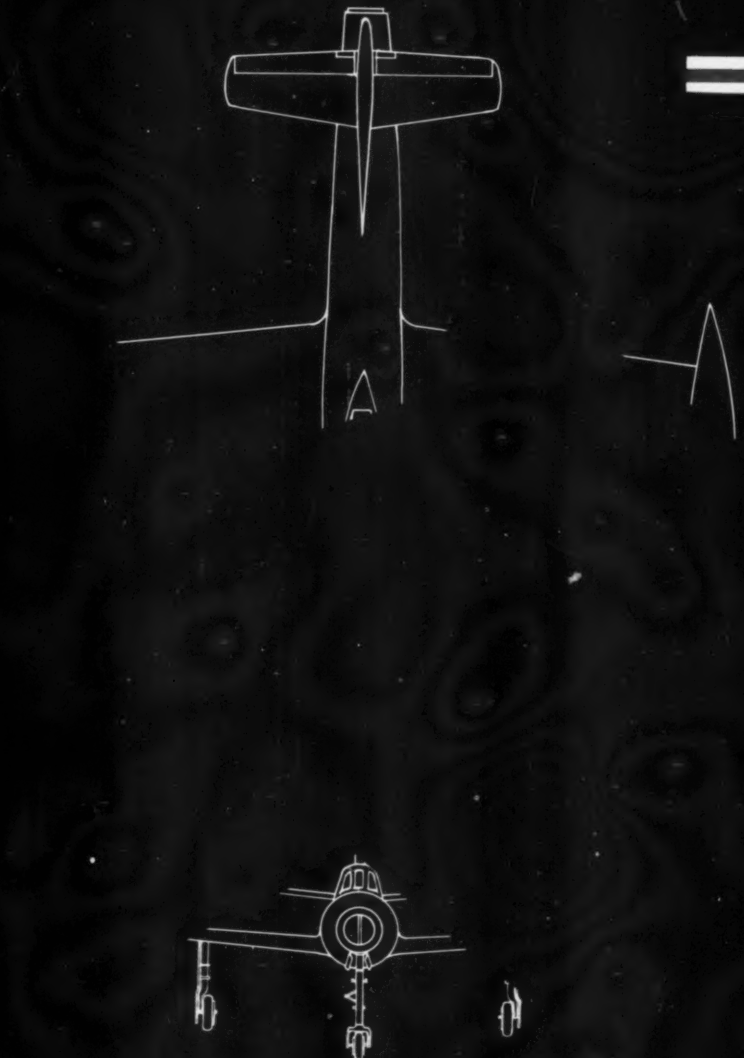


METAL PROGRESS

Cut Production Costs

LATROBE

DESEGATIZED BRAND

HIGH SPEED STEELS
HI CARBON – HI CHROME DIE STEELS

*** FULL UNIFORMITY**

*** QUALITY CONTROL**

Latrobe's Desegatized Brand high speed steels and hi carbon - hi chrome die steels will help you cut production costs. Rigorous quality control - from material selection through product inspection - plus the full uniformity found in all Desegatized Brand steels assures better tool and die performance and longer production life.

In Desegatized Brand steels, the all-important carbide particles are evenly distributed throughout the entire cross section - NO HARMFUL CARBIDE SEGREGATES ARE PRESENT! This results in extra toughness and strength . . . cracks, checks and warpage in heat treatment are radically minimized . . . superior machining and grinding abilities result.

Specify Latrobe's Desegatized Brand tool and die steels for better performance and resulting lower production costs.

Send for booklet "WHY DESEGATIZED" showing superiority of Desegatized Brand steels over average standard process steels.

LATROBE ELECTRIC STEEL COMPANY

LATROBE, PENNSYLVANIA

Branch Offices and Warehouses located in: DETROIT, TOLEDO, DAYTON, PITTSBURGH, LOS ANGELES, PHILADELPHIA, CHICAGO, CLEVELAND, NEW YORK, BOSTON, SEATTLE, MILWAUKEE, HARTFORD, ST. LOUIS, BUFFALO.

Sales Agents: DALLAS, HOUSTON, WICHITA, DENVER, BIRMINGHAM.

WHY RISK THIS TO SAVE A DIME A WEEK?

The scrap pile of many a plant—whether it makes gears, bricks or gummed tape—thrives on poor temperature control. And the margin is often narrow . . . a variation of only a few degrees meaning thousands of dollars in rejected material or damaged equipment.

Yet many plants risk this loss without realizing it! They attack the temperature control problem correctly, by using potentiometer pyrometers to get top accuracy and dependability. But they sometimes slip on the "standardizing" adjustments which such instruments need to maintain those qualities. Overlooking the need for frequent and regular standardizing, these plants permit the operation to be done by hand . . . and thus possibly skimped or forgotten.

There is just one way of removing this threat to the accuracy of process temperature. It's by putting the standardizing responsibility where it belongs . . . directly on the recorders and controllers themselves.

A relatively simple device, the automatic standardizer, should be built into the potentiometer to handle this job. It checks the measuring circuit at least every 48 minutes . . . adjusts when necessary . . . *never forgets!* And this essential feature, amortized in the usual 10 years, costs less than 10¢ a week.

So, regardless of what make instruments you buy, be sure to specify automatic standardizing. It's cheap . . . safe . . . sure!

Write Leeds & Northrup Company, 4927 Stenton Avenue, Philadelphia 44, Pennsylvania.

AUTOMATIC STANDARDIZING
Guards Product Quality When You Use Instruments Like These

Speedomax Potentiometer Instruments and Drive Unit (left) helping maintain production in an Ohio metal-working plant.

Jrl Ad ND4(3)

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

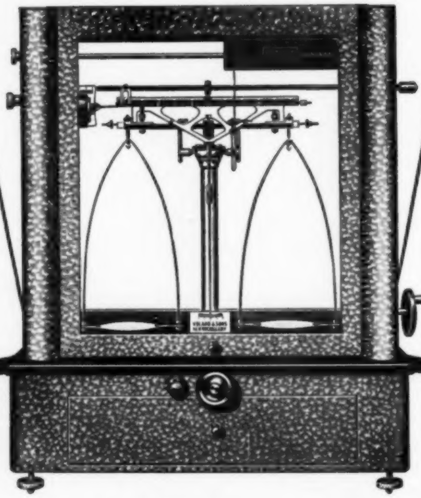
Metal Progress is published and copyrighted, 1951, by American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879


How to make more with less steel...
Whether you make dragline buckets feed troughs truck trailers with Inland HI-STEEL, you can retain the same structural strength yet save enough steel on every three units to fabricate a fourth one! Where payload is important extreme strength and elimination of deadweight essential HI-STEEL is the answer. When you must make your product stronger or make it lighter or make it last longer without increasing your steel tonnage HI-STEEL is the answer. HI-STEEL's yield point is nearly twice as high as ordinary structural-grade carbon steel, plus superior notch toughness and fatigue strength. HI-STEEL's resistance to atmospheric corrosion is four or five times as much as ordinary carbon steel. Abrasion resistance may be improved as much as 12 times over ordinary carbon steel, depending on the abrasive medium. No change in shop practice is ordinarily required when fabricating HI-STEEL.
INLAND HI-STEEL
INLAND STEEL COMPANY: 38 So. Dearborn St. Chicago 3, Ill.
SALES OFFICES: Chicago, Davenport, Detroit, Indianapolis, Kansas City, Milwaukee, New York, St. Louis, St. Paul

Delivery from HARSHAW Stock

VOLAND ANALYTICAL BALANCE Series 300

with Visigram, Notched Beam, and Magnetic Damper



It's an Ideal Combination of Accuracy and Speed

This balance is especially useful in general laboratory work where accuracy combined with speed is required. Although sensitive to .05 milligrams under full load, it withstands rough usage. This moderately priced balance possesses features which provide convenience in weighing, speed, and accuracy usually found only in higher priced balances.

About the VISIGRAM—

The VISIGRAM is a direct reading device which greatly increases accuracy, speed and convenience of analytical weighing.

The VISIGRAM uses the chain to give a DIRECT READING of weights below 0.1000 gram. The weight is read in numerals on a counter at the eye level. The inconvenience of interpolating a vernier is eliminated and inaccuracies due to parallax or other visual distortions are non-existent.

A reading is made instantly and accurately to the fourth decimal place and the fifth decimal place can be estimated if desired.

The VISIGRAM is equipped with ball bearings throughout, which insures smoothness of operation, so that the maximum weighing accuracy can be maintained. A simple equilibrium adjustment is provided.

The device has been carefully designed so that all working parts of the balance are in view and accessible.

H-2460-50—Voland Analytical Balance with VISIGRAM, notched beam and built-in Magnetic Damper **$355.00**

Specifications

Capacity: 200 grams on each pan.
Knives: Selected agate.
Sensitivity: .05 milligrams with full load.
Bearings: Optically flat polished agate.
Beam: Hard rolled aluminum alloy 6″ long.
Arrestment Mechanism: Vertical with three-point support.
Cabinet: Aluminum.
Base: Black Slate.
Pans: 2.5″ diameter, polished, with chromium plated bows.
Visigram, Notched Beam: Dumb-bell shaped rider with fork mechanism prevents rider from falling off beam. Provides 1.1 grams without additional weights or riders. Equipped with equilibrium adjustment mechanism with built-in Magnetic Damper.

HARSHAW SCIENTIFIC
DIVISION OF THE HARSHAW CHEMICAL CO.
CLEVELAND 6, OHIO

Cleveland, Ohio
Cincinnati, Ohio
Detroit, Michigan
Houston, Texas
Los Angeles, Calif.
Philadelphia, Pa.

How Christiansen Corporation has grown to serve you

Christiansen Corporation, and its subsidiary and affiliated companies, has for over a quarter of a century been active in development and progress of structural steel uses . . . aluminum and its general applications . . . and in magnesium production and fabrication from its inception in this country.

Since start of manufacture in 1914, its patented line of expanded steel poles, joists and other light structural steel building products has gained an international reputation. This expansion method of manufacture affords the lightest structure possible for equal strength.

Further product diversification, in line with the growing importance of "the light metal age", added production of non-ferrous alloy metals in ingot form as well as general magnesium fabrication and aluminum casting manufacture. Specific products for the foundry industry are Aluminum Alloy Ingot, Zinc Base Die Casting Alloys, and Magnesium Bottom Boards. Magnesium fabrication includes manufacture of such products as Dockboards, Maritime Gangplanks, Hand Trucks, Tote Boxes, Barrel Skids, and Grain Shovels as well as general fabricating work in the experimental, industrial, and military fields. Manufacture is conducted by use of all the modern equipment for complete fabrication work including the processes of deep drawing, forming, welding and joining.

Through its various integrated company operations, Christiansen Corporation is in a unique position to care for customer requirements. In purchase of its products you are assured of receiving continuous high quality of material designed or engineered for your specific needs.

The Christiansen Corporation policy of guaranteed quality and service offers an efficient buying course for you.

EDCO
CHRISTIANSEN CORPORATION

CHRISTIANSEN CORPORATION

[illegible]

Plants • Chicago, Illinois
East Chicago, Indiana
Chicago Heights, Illinois

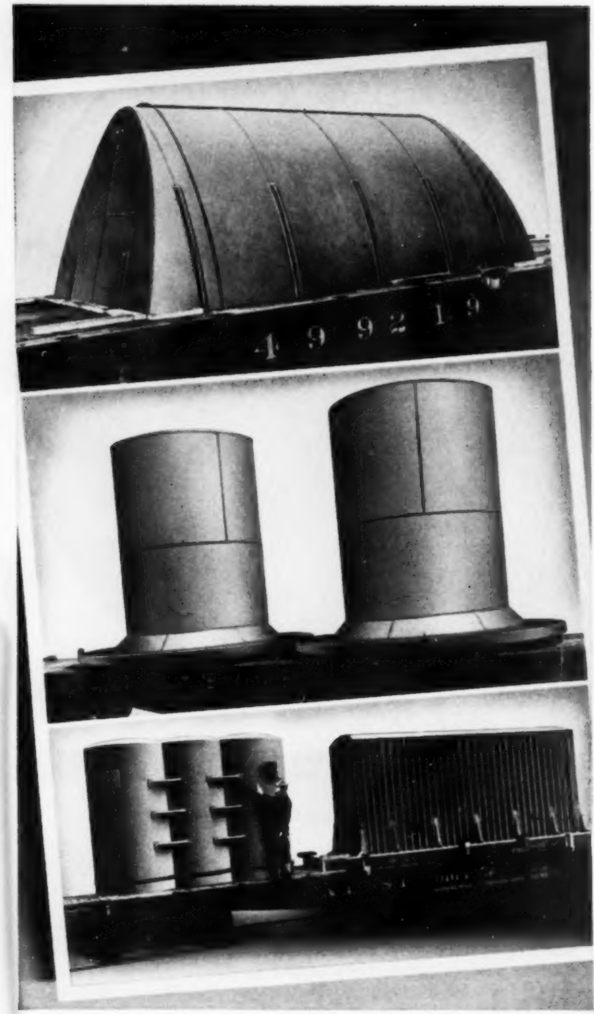
Waukesha Motor

Heat treating trouble came to the Waukesha Motor Company, Waukesha, Wisconsin, recently. Several key parts for various engine models would not harden uniformly or wash easily.

A Cyanamid technical service representative was called, and came to the plant. Here he worked in close cooperation with Waukesha engineers. Combining their knowledge, they analyzed the problems . . . and found practical, effective solutions in each case with one product—AEROCARB E and W Carburizing Compounds.

The Waukesha case is typical of the way Cyanamid service and heat treating compounds can work together to solve your metal treating problems and help you meet the high specifications required on civilian and defense contracts, so:

Next time, call Cyanamid first.



WOULD BIGGER COVERS CUT YOUR ANNEALING COSTS?

The operating economies of large annealing covers is obvious. Handling time is shortened when one cover replaces as many as eight. And larger covers permit larger volumes to be treated in each anneal. But installation records of large PSC covers show that other less obvious savings are effected. Made of light-gauge welded sheet alloy, they attain heat in less time; and they handle easier and faster. Being less bulky, PSC covers increase furnace capacities.

PSC "Light-Weight" Construction Makes Much Larger Covers Possible

We have made annealing covers as long as 21 feet. Because of the light-weight nature of PSC construction there is really no limit to the size of cover we can furnish. We fabricate from any alloy to meet your firing requirements. We invite you to take advantage of our 20 years experience in fabricating covers for the majority of the nation's steel mills and many leading foundries.

Weigh Up to 2/3 Less

All units in The Pressed Steel Co. complete line of heat-treating equipment, listed at right, are made of light-gauge welded sheet alloy. On the average, they weigh 2/3 less than cast equipment, resulting in outstanding savings. Yet their service life is 2 to 7 times that of cast equipment.

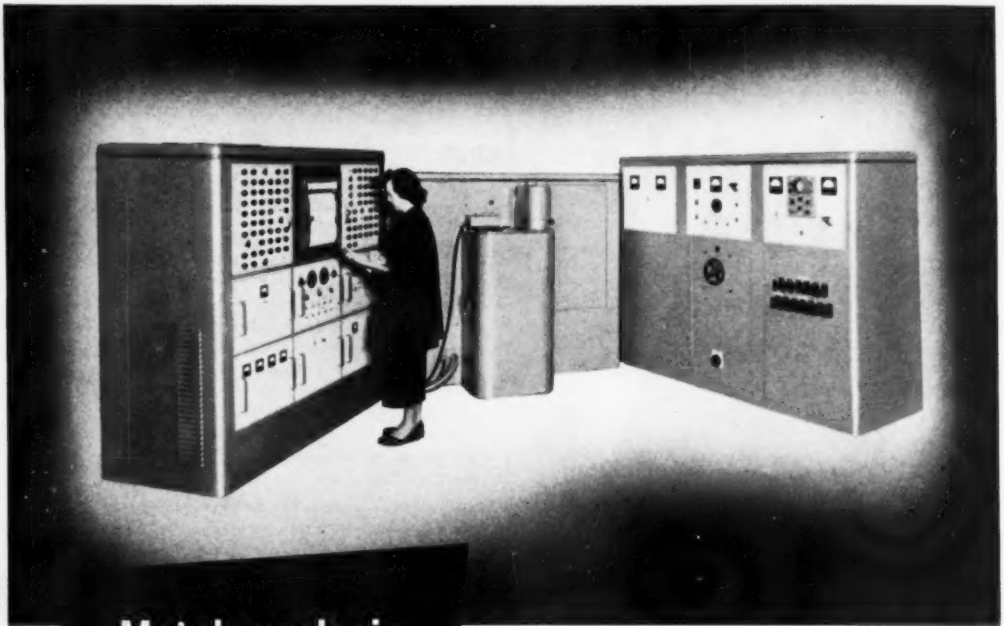
Light-Weight
Heat-Treating Equipment for Every Purpose

Carburizing & Annealing Boxes	Tumbling Barrels · Tanks
Baskets · Trays · Fixtures	Cyanide and Lead Pots
Muffles · Retorts · Racks	Thermocouple Protection Tubes
Annealing Covers and Tubes	Radiant Furnace Tubes & Parts
Pickling Equipment	Heat, Corrosion Resistant Tubes

THE PRESSED STEEL COMPANY
of WILKES-BARRE, PENNSYLVANIA

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

☆ ☆ ☆ OFFICES IN PRINCIPAL CITIES ☆ ☆ ☆



Metal analysis in 2 minutes...

with ARL Production Control Quantometer

Representing the most advanced type of direct-reading spectrometer yet developed, this multiple-purpose instrument provides pen-and-ink recorded analyses of samples, element by element, almost instantaneously. These graphic records may be made in multiple for high-speed analytical control.

The instrument can be designed for many purposes, including testing of metal alloys and other inorganic materials. As many as 25 elements can be measured with one instrument—up to 20 simultaneously. Individual units are not limited to one type of analysis but can be designed for diverse and versatile service to meet the requirements of several major plant problems. Results are comparable to chemical analyses in accuracy.

The latest and most elaborate unit in the complete ARL line of spectrochemical equipment, the ARL Production Control Quantometer offers the modern scientist the equivalent of a complete laboratory in one compact unit. Manufactured by the world's oldest and largest producers of direct-reading instruments, the Quantometer is available to help you in your analytical and production problems. Write for complete details.

Leader in Performance

No other instrument in this field offers you so many outstanding features for obtaining complete, accurate, high-speed chemical analyses.

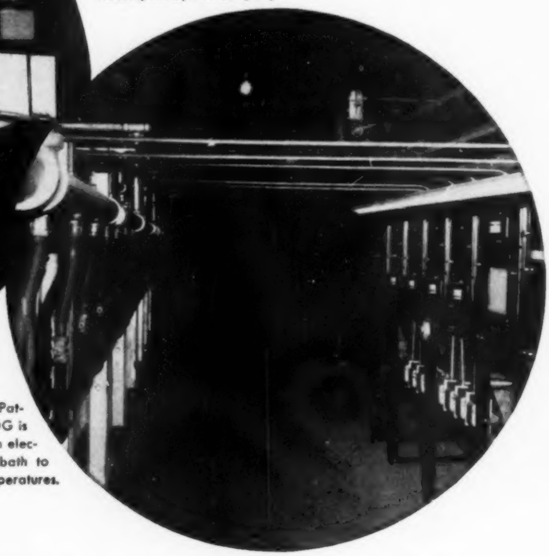
Leader in Popularity

ARL Production Control Quantometers are in daily use in all fields of metal analysis.

APPLIED RESEARCH LABORATORIES

4336 San Fernando Road, Glendale 4, California
New York, Pittsburgh, Detroit, Chicago, Los Angeles

At Viceroy Manufacturing Company—Rubber Goods. This leading Canadian company uses CAPACILOGS to obtain and record true temperatures of rubber products being moulded in a continuous rotary curing machine developed by the company.



At Macwhyte Company—Wire Patenting. Here the CAPACILOG is used on the entering end of an electrically heated nitrate salt bath to control and record temperatures.

instru*mentality* in action...for accuracy

Accurate to a point which exceeds the need in normal process applications throughout industry—that's the Capacilog—another example of Wheelco Instru*mentality* in action. It's a direct reading, deflection type strip chart recorder which gives you measurement, indication, and control with a permanent record of temperature, speed, static strain loads, AC-DC voltage, amperage and other electrically measurable factors.

Economy—uninterrupted service and accuracy are the leading reasons why more and more manufacturers are specifying the Wheelco Capacilog for more profitable use of process equipment.

Write today for Bulletin C-2 ... complete illustrated details of the CAPACILOG ... construction ... specifications ... advantages.

Wheelco Instruments Company, 835 West Harrison Street, Chicago 7, Illinois

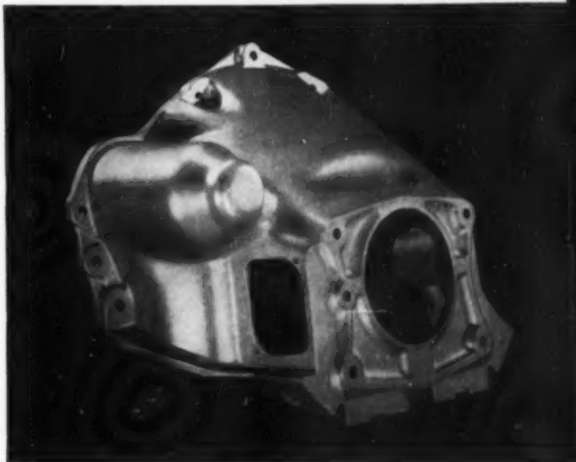
wheelco *electronic controls*

Government regulations limit the use of aluminum for other than essential projects. The facts presented here are to help you speed this essential work and get the most out of available metal.

Suggestions on how designers can utilize it for faster, lower-cost production . . . capitalize on advantages that only the light metals provide

CONTENTS

Aluminum Die Castings



New developments are making possible larger and stronger die castings in aluminum. This case history of an automotive clutch housing shows how an Alcoa die casting made a part stronger and less expensive, too.

This clutch housing supports half the engine's weight. It is highly stressed, must absorb vibration. Originally, these housings were made of cast iron. Designers recognized the advantages to be gained by the use of a properly engineered aluminum casting.

After extensive development by our engineers, an aluminum die casting capable of withstanding the stresses was designed. Using a sand casting alloy of comparable mechanical characteristics to the die casting alloy selected, we poured sand castings and machined them to the die casting dimensions. Alcoa's Research Laboratories measured the casting's resistance to shear static loads, bending stresses and dynamic stresses. Using these test results, designs were modified and die-casting dies built.

While the auto maker conducted actual road tests with the *die castings*, we repeated the lab tests. Result: The die casting is 25% stronger in shear, 10% stronger in bending, 100% better in fatigue life, costs substantially less than the cast-iron product.

ALCOA

ALUMINUM COMPANY OF AMERICA • 1805D GULF BLDG., PITTSBURGH, PA.

Finishing Aluminum

Aluminum takes all finishes — any that other metals will take, plus anodic coatings possible *only* with Aluminum

Aluminum is easy to plate by commercial processes

To simplify the plating of aluminum, Alcoa has developed the zincate-bath method. A 30-second to 1-minute immersion in this bath deposits a uniform layer of metallic zinc tightly bonded to the aluminum base. You can then plate with any metal and by any method compatible with zinc.

The zincate bath consists of 525 grams 76% caustic soda and 100 grams zinc oxide dissolved in water to make 1 liter. When suitably cleaned aluminum parts are immersed in this solution, the aluminum oxide film immediately dissolves, exposing the underlying metal. Some of the exposed aluminum then dissolves and is replaced by an equivalent weight of metallic zinc.

A copper strike is applied over the zinc-immersion layer. The zincate-bath method is less critical than others used in plating aluminum and gives uniformly good results.

If you need wear-resisting aluminum parts, you can give aluminum a "file hard" coating

To make aluminum suitable for applications once monopolized by stronger, harder metals, Alcoa has developed a special anodized coating. In this process, an integrally bonded oxide film of controlled thickness and predetermined hardness is deposited on aluminum parts.

Applications for this coating include bearing races, pistons, moving joints, and any parts where light weight must be combined with high resistance to frictional wear and abrasion.

For a complete story on aluminum's remarkable affinity for every type of finish and every commercial finishing method, write for a copy of the 64-page book, "Finishes for Alcoa Aluminum."

ALCOA

ALUMINUM COMPANY OF AMERICA • 1805D GULF BLDG., PITTSBURGH, PA.

Aluminum Screw Machine Stock

Aluminum screw machine parts offer the designer many interesting physical properties. Their lighter weight can result in substantially lower costs.

Because aluminum is light in weight, a pound of aluminum may produce three times as many parts as a pound of steel or brass . . . usually enough to offset any difference in material cost.

Because aluminum can be machined easily and at high speeds, your parts can cost less to make in aluminum. Speed of machining is often limited only by the speed at which your machines can be operated.

Because aluminum is corrosion resistant, it is ideal for fittings and similar parts that are subject to corrosive conditions. Similarly, any aluminum components should be fastened with aluminum fasteners. This will prevent galvanic corrosion caused by contact of dissimilar metals.

Aluminum machines to an excellent finish . . . often needs no protective coating. But, if you want further finishing, aluminum takes any commercial finish that can be applied to other metals — plus anodizing, that is possible only with aluminum.

Magnesium

Lightest of commercial metals, its direct substitution for other materials often provides important ways to reduce weight and increase strength, as this case history shows.

Fruehauf Trailer Company Eliminates 560 Pounds of Dead Weight per Trailer with Light, Strong, Extruded Magnesium Floors

Designed as extruded sections, with deep, multiple channels, this flooring has none of the disadvantages of wood flooring . . . weighs 50% less, a saving of about 560 pounds in standard 30-foot trailer. In addition to light weight and high strength, it is free from splintering and warpage. It won't absorb water

ALCOA ALUMINUM

ALUMINUM COMPANY OF AMERICA • 1805D GULF BLDG., PITTSBURGH, PA.

Magnesium (continued)

. . . is easy to keep clean and sanitary. It withstands the shock and abuse of lift trucks.

By utilizing magnesium and aluminum in its trailers, Fruehauf has reduced over-all weight by nearly 1200 pounds.

Due to its extremely low specific gravity, magnesium structures can usually be made lighter than aluminum, and considerably lighter than steel.

It can be cast, forged, extruded . . . joined by any method, including resistance welding and resin cements. It is the easiest of all metals to machine . . . can be machined at surface speeds impossible with other metals. Good housekeeping practices permit machining with complete safety.

Alcoa offers a 330-page textbook called, "Designing with Magnesium." You'll find it worth while to write for your personal copy.

ALUMINUM COMPANY OF AMERICA • 1805D GULF BLDG., PITTSBURGH, PA.

SAVES 4½ HOURS . . . Martin-Quaid Co., of Philadelphia, Pa., used the New Aircomatic Process to reduce the time and cost of welding huge stainless steel cylinders used in the manufacture of carpets. They found this revolutionary process cut materials cost 25% . . . and saved 4½ hours working time over the old method – and, at the same time, greatly increased the quality of the finished product.

REDUCES TIME ⅘'s . . . Consolidated Welding and Engineering Company, of Chicago, Ill., adopted the new Aircomatic process for welding aluminum separators. Immediately, major production and cost problems were solved: To weld one complete separator assembly took only 90 man hours – about 1/5 the time of other methods.

Further, Aircomatic's high current density and the attendant high welding speed confined the heating effects to the narrow weld-zone . . . completely eliminating distortion.

ELIMINATES LEAKS . . . Griffin & Company, of Louisville, Ky., found Aircomatic's high speed and the ability to make welds without interruption ideally suited to the fabrication of tanks for all-aluminum evaporative coolers. Production time and cost was cut to the minimum, and warpage and distortion were completely eliminated. Thus far, the company has made hundreds of these tanks without a single leak.

BOOSTS PRODUCTION 71% . . . The Stewart-Warner Corporation, South Wind Division, Indianapolis, Ind., join the upper and lower halves of its "Safe-Air Gas Home Heater" with the completely new, high-speed Aircomatic Process. This time-saving, cost-cutting process skyrocketed production 71% . . . and cut manufacturing costs in proportion.

A new Aircomatic motion picture "The Tool For The Job" is available for specialized groups. Ask your nearest Airco office about showings.

AIRCO

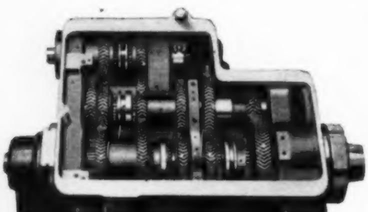
AIR REDUCTION

AIR REDUCTION SALES COMPANY • AIR REDUCTION MAGNOLIA COMPANY
AIR REDUCTION PACIFIC COMPANY
REPRESENTED INTERNATIONALLY BY AIRCO COMPANY INTERNATIONAL
Divisions of Air Reduction Company, Incorporated
Offices in Principal Cities

Tumbling Barrels . . to Resist Corrosion and Abrasion. These barrels are subject to extreme wear from small parts being cleaned by the swirling agitation of caustic solution and abrasives. For extra-long life, they are fabricated from wear- and corrosion-resistant Ampco Grade 8 sheet, carbon-arc welded with 5/32" Ampco-Trode 160 coated electrodes used as filler rods.

Ampco Extrusions available as solid rod and/or tube in rounds or simple shapes. From Ampco's own 2275-ton hydraulic press and extrusion mill. Their use saves metal, machining time, and costs. Superior grain structure and exceptionally high strength are assured — *plus* close tolerances and good surface finish.

Ampco Metal Cam . . . for Smooth Action, Extreme Wear-Resistance. Ampco Grade 20 selected because it actually outlasts hardened steel with twice the Brinell hardness. This is due to its extreme wear-resistance and the smoother action of bronze against steel. Also ideal for rollers, gibs, slides, wearplates, forming dies on light-gauge steel and welding jaws.

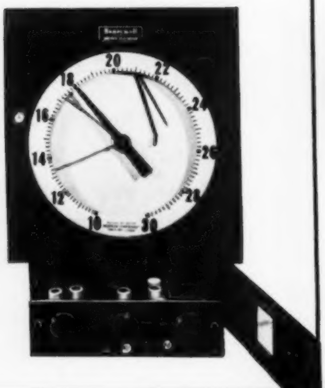


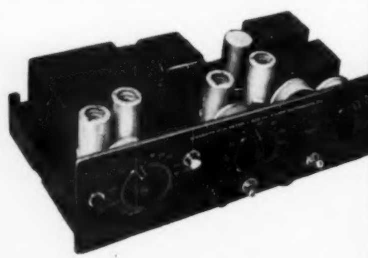
Ampco Bushings in High-Speed Headstock . . . for High Wear-Resistance. There are 16 Ampco Grade 18 Bushings in this one headstock: 14 on loose-running gears, 2 on the center bearing of the intermediate shaft and main spindle. Ampco Grade 18 chosen as ideal alloy because of the heavy gear loads and high spindle speeds. Extra life assured by high tensile (77-85,000 psi), and Brinell hardness of 159-183.

Stock Bars of Grade 18 Ampco Metal . . . for Production and Maintenance where long life is important.
Wear-resistant. Have exceptional impact and fatigue characteristics. Centrifugally cast to provide dense, fine grain structure free from impurities. Readily machinable. Ideal for bearings, bushings, gears, worm wheels, slides, guides and other wear applications. Available from stock in 12½-inch lengths from 2½-inch to 6-inch OD. or solid bars ½" to 4½" diameter, cut to desired lengths.

Here's Better Control
for your
Furnace or Process

BROWN INSTRUMENTATION IS THE *Plus-Factor*



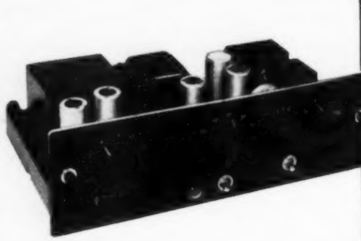


Position - proportioning control with automatic reset... Electr-O-Line.

Electr-O-Line

Electric Proportional Control Relay
With Automatic Reset

*The **Electr-O-Line** delivers a continuous heat input which is modulated according to exact process requirements. Individual control adjustments are included for proportional band, reset rate, approach rate and sensitivity. For complete information write for Specification Number 194.*



Electr-O-Pulse

Time-Proportioning control with automatic reset... Electr-O-Pulse.

Electric Proportional Control Relay
With Automatic Reset

*The **Electr-O-Pulse** delivers an intermittent full heat input which is modulated on a pulse/time basis according to exact process requirements. Individual control adjustments are included for proportional band, reset rate, approach rate (optional) and cycle time. For complete information write for Specification Number 195.*

Electr-O-Line and *Electr-O-Pulse* proportional control relays provide the sensitivity and accuracy required for the most critical control problems. The control adjustments are totally independent of each other, an exclusive feature.

Thus, when one control adjustment is changed, the others are not upset. The relays are designed to withstand severe industrial conditions, and are unaffected by vibration . . . compact unit construction makes for easy installation and service. Both are available mounted integrally with the *ElectroniK* proportional controller, or separately for modernizing existing installations . . . both produce the same straight line control.

Your local Honeywell engineer can give you recommendations for control systems utilizing these relays, or any other type of control, to suit your specific requirements. Call him in today . . . he is as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4503 Wayne Ave., Philadelphia 44, Pa. Offices in more than 80 principal cities of the United States, Canada and throughout the world.

MINNEAPOLIS **Honeywell**
BROWN INSTRUMENTS

FORGINGS BY FINKL

"Forgings by Finkl" . . . a byword in the industry . . . the best obtainable. "Forgings by Finkl" means that skilled craftsmen, employing modern methods and machinery, have selected the best steel for the job and created the best job from the steel. And to doubly insure long life and economical performance, each step in the development of the forging is thoroughly checked metallurgically. Nothing is taken for granted.

A medium size forging, illustrated above, is the top head for a 2,000 ton hydraulic press. It is made of C-1045 steel, normalized and drawn in one of Finkl's heat treating shops. Forged from a 59" ingot, the rough machined forging shown weighs 22,800 pounds. Whether carbon or alloy steel, the Finkl organization can easily handle any job from a few pounds up to 50,000 pounds apiece.

Write or phone when you are ready to talk about or plan your forgings. The experience of Finkl Sales Engineers is available to you.

F

MANUFACTURERS OF THE LARGEST FORGINGS IN THE MIDDLE WEST

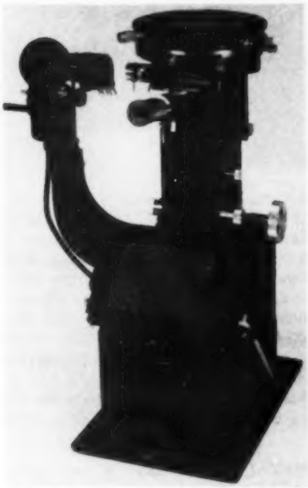
A. Finkl & Sons Co.

2011 SOUTHPORT AVENUE • CHICAGO 14

DIE BLOCKS & INSERTS • PISTON RODS & RAMS • SOW BLOCKS • CRANKSHAFTS

Engineering Digest of New Products

CAMERA MICROSCOPE: A universal camera microscope for metallurgical work, said to be the most compact and easiest to operate equipment of its kind, is being distributed

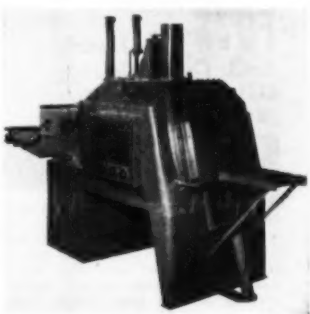


by William J. Hacker & Co., Inc. It has a built-in camera and a magnification of from 4.5 to 2200 times. Among the outstanding features of this instrument are instant changeover from bright to dark field illumination, instantaneous transition from visual observation to photography and from ordinary to polarized light. Methods of illumination include vertical (bright field), oblique internal (bright field), flat oblique multilateral (dark field), and unilateral external (dark field).
For further information circle No. 266 on literature request card on p. 480B

SQUARING SHEAR: A shear with a capacity of 20 ft. of ½-in. mild steel plate is the latest addition to the line manufactured by The Cincinnati Shaper Co. Believed to be the longest ½-in. shear ever built, this machine weighs over 135,000 lb. and has a speed of 20 strokes per minute. It is equipped with hydraulic hold-downs capable of exerting a force of over 70 tons. The shear has a 24-in. throat or gap and a 48-in. back gage range.
For further information circle No. 267 on literature request card on p. 480B

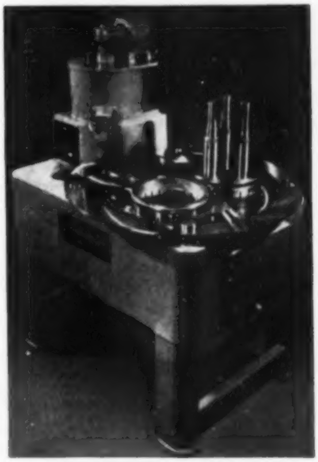
PIPELESS PRESS: Development of a new principle in hydraulic press construction is announced by Elmes Engineering Div., whose new metalworking presses contain no piping in the main hydraulic circuit. All high-pressure fluid is conducted through short, direct passages drilled in the structural parts. Exceptionally smooth and shockless operation virtually eliminates vibration. Any Elmes hydraulic metalworking press can be supplied with pipeless construction.
For further information circle No. 268 on literature request card on p. 480B

HEAT TREATING FURNACE: A new semi-automatic controlled atmosphere unit for bright heat treating, rated at 100 lb. per hr., has been announced by Ipsen Industries, Inc. Maximum operating temperature is 2100° F. The unit consists of a furnace sealed to a combination cooling chamber and quenching tanks. The work is manually loaded into the furnace and the transfer from furnace to cooling or quenching section is done



without breaking the atmosphere seal. The furnace is electrically heated, using 8 bars for 16-kw. input. The cooling chamber is water jacketed, with automatic temperature control.
For further information circle No. 269 on literature request card on p. 480B

ATTACHMENTS FOR LAPPING: Two new attachments for the Crane Packing Co. Lapmaster enable users to speed production and simplify handling of certain types of



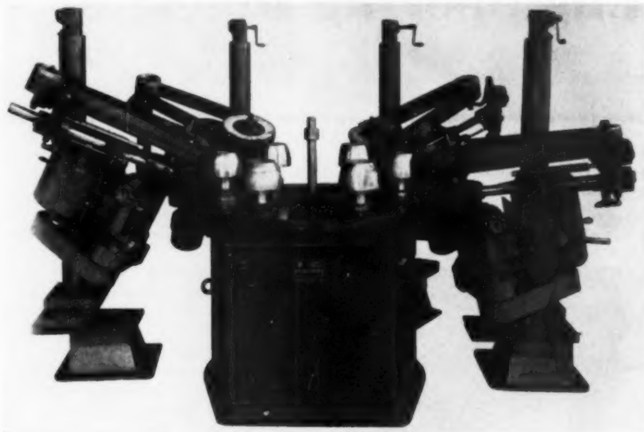
parts. These developments, the "roller bar" attachment and pneumatic lifts, permit a wider range of lapping work. The roller bar attachment *(see cut)* was designed primarily to facilitate loading and unloading of tall or large parts. Complete accessibility of the lap plate is afforded, height of parts is unlimited, and large heavy castings lap of their own weight.
For further information circle No. 270 on literature request card on p. 480B

RECORDER: A new Speedomax electronic recorder announced by Leeds & Northrup Co. features a range continuously adjustable over a 20-to-1 ratio, and zero suppression adjustable over more than twice the maximum range. Through use of a particular suppressed zero range, an operator can ignore that portion of the range in which he is not interested, while he spreads the few millivolts he wants to watch across the entire width of the instrument chart. Adjustable range permits the user to select his own scale calibration at will.

Some typical measurements in-

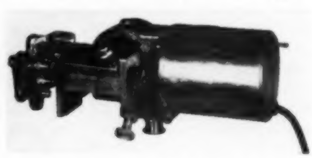
clude: *(a)* measurements with strain gages, *(b)* temperature difference measurements with thermocouples and *(c)* speed measurements. Calibrated d-c millivoltage range is adjustable from a minimum across-chart span of 1.1 mv. to a maximum range span of 22 mv. Uncalibrated coarse and fine rheostats provide maximum zero suppression of −50 or +50 mv., continuously adjustable between these limits. These adjustments are independent. Range remains constant during zero adjustment; zero suppression remains constant during range adjustment.
For further information circle No. 271 on literature request card on p. 480B

HARD-FACING ROD: The Alloy Rods Co. has announced a new oxy-acetylene welding rod for hard facing. It is centrifugally cast, consisting of wear-resistant chromium carbides contained in a hard iron-chromium-manganese alloy matrix. Hardness of deposited metal is Rockwell C-56 to 58.
For further information circle No. 272 on literature request card on p. 480B



POLISHING AND BUFFING: A newly developed polishing-belt arm attachment which is universally adjustable from horizontal to vertical positions has proved unusually effective in a new 40-in. rotary automatic polishing and buffing machine arrangement developed by Acme Manufacturing Co. The machine shown is a six-station indexing rotary with four Acme adjustable floating head buffing lathes equipped with the new polishing-belt arm attachment. The machine has a 1-sec. indexing interval, the same as all Acme indexing rotaries.
For further information circle No. 273 on literature request card on p. 480B

METAL SPRAYING: A new metal spraying gun, designed especially for coating shafts, rolls, or machine element parts from a lathe mounting, has just been introduced by the Metallizing Co. of America. This gun, called the Mogulectric, weighs 20 lb., is designed principally for stationary operation, and is powered with a 1/20-hp. constant-speed induction motor, assuring a uniform wire speed



that can be adjusted to the type of metal being sprayed. With it, a spray job can be completed in one-half to two-thirds less time than is possible with any air-driven metal spraying unit. Speed is rated up to 18 lb. per hr. for aluminum and nickel, up to 80 lb. per hr. for zinc. Only one adjustment is necessary — that of the vari-

able speed indicator which is regulated according to the metal being sprayed.

Gas requirements are minimum. For example, when spraying $\frac{3}{16}$-in. stainless steel, the Mogulectric uses 44 cu.ft. of acetylene and 68 cu.ft. of oxygen per hr. The air used to atomize and carry the metal to the surface being coated is 16 cu.ft. per min. at 45 lb. pressure.
For further information circle No. 274 on literature request card on p. 480B

NIBBLING MACHINES: Campbell Machine Div. has announced a new line of nibbling machines, which will cut odd shapes of ferrous and non-ferrous metals quickly, cleanly and inexpensively. Campbell nibblers cut

from 40 to 60 times faster than drilling and filing. Work can be fed equally well in any direction because it is cut with a rapidly moving circular punch which operates over a circular die. Pieces need very little finishing and intricate shapes can be cut easily. The model shown will cut low-carbon steel up to ⅜ in. thick and stainless up to ¼ in.
For further information circle No. 275 on literature request card on p. 480B

POLISHING HEAD: A new portable brush-backed polishing head has been developed by the Vonnegut Moulder Co. The head consists of two principal parts: an outer shell or drum, holding sixteen replaceable brushes, and a center spool on which are coiled sixteen strips of abrasive cloth. In operation, the brush bristles force the abrasive tips into depressions and also allow them to ride over projections of the workpiece surfaces. This ability to follow irregular surfaces instead of reshaping them makes the head well suited for finishing operations on all classes of shaped surfaces. Since an entirely different set of results may

be obtained with the same head, simply by changing the grade and grit of abrasive strips used, its applications are broad.
For further information circle No. 276 on literature request card on p. 480B

DUCTILE BISMUTH WIRE: Fitzpatrick Electric Supply Co. announces the successful production of ductile bismuth wire and ribbon. The company has bismuth ductile enough to wind on its own diameter at room temperature. The possibilities of development in the control and instrument fields by the use of ductile bismuth are great. Bismuth is stated to offer the following characteristics in excess of other materials: *(a)* resistance change in a magnetic field, *(b)* voltage change due to the Hall effect, *(c)* variable rectifier — in fact, the only variable rectifier known, *(d)* hot and cold junction for instrumentation, *(e)* most negative material known for thermocouples, and *(f)* the best material for resistance change due to temperature change for instrument control.
For further information circle No. 277 on literature request card on p. 480B

THORIATED TUNGSTEN: A new tungsten electrode which will reduce inert-arc welding costs has been announced by General Electric Co. Major applications will be for inert-arc welding with direct current, straight polarity, using either argon or helium gas. The new electrode will produce a stable arc over a wider range of currents and will resist contamination by weld metal, resulting in over ten times normal life. The arc tends

to stay under the electrode and will not wander or climb up the electrode at low currents, assuring consistent ease of operation. Touch starting is easily accomplished with currents as low as 5 amp. The new electrode is manufactured in 3 to 24-in. lengths and from 0.040 to $\frac{1}{4}$-in. diameters. It is not recommended as a standard tungsten replacement for reverse polarity d-c, a-c welding, or atomic hydrogen welding.
For further information circle No. 278 on literature request card on p. 480B

DEEP DRAWING COMPOUND: Pillsbury Chemicals announces a new compound for deep drawing of a wide variety of steel. It also draws aluminum efficiently. Nonpigmented and water soluble, the new No. 527 is easily diluted, can be mixed to any consistency quickly and usually exceeds pigmented compounds in efficiency. It is being used successfully "ahead of porcelain". Any type of cleaner can be used to remove the compound.
For further information circle No. 279 on literature request card on p. 480B

MULTIPOINT RECORDER: Wheelco Instruments Co. is now in production on a new multipoint Capacilog. The electronically operated unit is a deflection-type strip chart recorder which provides up to six permanent records on one chart. Measurement may be obtained with sensing units producing electric signals, such as thermocouples and radiation detectors. This deflection-type system is a direct-reading, nonbalancing method which achieves results heretofore obtainable only through the use of potentiometric or null-type systems (accuracy to $\frac{1}{4}$ of 1% of scale).
For further information circle No. 280 on literature request card on p. 480B

SILICONE FINISH: A new heat-resistant finish, Sicon, formulated from a silicone base, exhibits unusual stability at temperatures as high as 1000° F., according to the manufacturer, Midland Industrial Finishes Co. Sicon has been proved on the production line for such products as industrial furnaces, heating units, incinerators, and similar products; and it is recommended by the manufacturer for protecting and preserving the surfaces of a wide variety of other products where ordinary heat-resistant finishes fail, such as mufflers, tail pipes, exhaust stacks, motorcycles, engine boilers, aircraft parts, electrical equipment, and high-temperature processing equipment.
For further information circle No. 281 on literature request card on p. 480B

PLATING CYLINDER: The Hanson-VanWinkle-Munning Co. announces the development of a new cylinder for barrel plating, made of Plexiglas, which is suitable for either cyanide or acid solution and can be carried through the entire cleaning, pickling and plating cycle. Only high-temperature Plexiglas, satisfactory for temperatures of 185° F., is used.
For further information circle No. 282 on literature request card on p. 480B

MOTORIZED TORCH HOLDER: A motorized torch holder for remote control raising and lowering of cutting torches through 5 in. of travel has been announced by Air Reduction Sales Co. Remote control switch box provides a switch to actuate each of four torches individually and a master switch for simultaneous control of all four torches. The holder can be positioned vertically, 90° left or right parallel to the longitudinal axis of the torch bar, and with an adaptor can be positioned 90° forward perpendicular to the horizontal axis of the torch bar.
For further information circle No. 283 on literature request card on p. 480B

PRESS BRAKE: The Airtherm Manufacturing Co. announces the addition of a new model to their line of power press brakes. Model 1510 enables bending of longer lengths of lighter metals — up to 10 ft. of 18-gage mild steel.
For further information circle No. 284 on literature request card on p. 480B

ELECTRIC FURNACE: A new electric furnace for heavy-duty heat treating work has been announced by Pereny Equipment Co. Over-all size is 33$\frac{1}{4}$ in. wide, 39$\frac{1}{4}$ in. long, and 64 in. high; with a loading area 18 in. wide, 24 in. long, and 18 in. high. Heating elements are of silicon carbide type; maximum connected load is 34.5 kw.; operating current, 220 volts 3-phase.
For further information circle No. 285 on literature request card on p. 480B

286. Aircraft Steels
New 68-page booklet on Aircraft Steels, inc ing a digest of many of the Air Force – N Federal and AMS specifications pertaining steel, plus the nearest corresponding AISI analy *Jos. T. Ryerson & Son, Inc.*

287. Alloy Conservation
New booklet showing graphically how as m as 30% of strategic alloying elements may saved through the use of clad metal sheet inst of solid sheet. Comparisons given for five h alloy types of sheet commonly used in h temperature applications. *American Cladmetals*

288. Alloys, Fabricated
Catalog available showing cost-cutting fabrica heat treating equipment for higher payloads better quality. *Rolock, Inc.*

289. Aluminum Forgings
To help you in designing for aluminum forgi a new book is offered, covering relation of for design to die sinking and relation of forging de to the manufacturing process. Also a section metallurgy gives all commercial alloy compositi physical properties and tolerances. *Alumin Co. of America.*

290. Armor Plate Furnaces
8-page description of continuous armor p lines and individual equipment for heating quenching both homogeneous and face-harde armor plate. *Drever Co.*

291. Castings, Centrifugal
Modern techniques of centrifugal castings permanent molds, for improved production i variety of alloy steels, described in 8-page lea complete with reference tables, drawings, ch and product photographs. *Lebanon Steel Foun*

292. Castings, Nonferrous
16-page anniversary book, "The Laving Vol. 6, No. 3, furnishes an interesting pict story of 50 years of outstanding contribution the nonferrous metal industry. Also gives tab information on nonferrous casting alloys and h ful notes on foundry practice. *R. Lavin Sons, Inc.*

293. Cemented Carbides
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294. Contour Projector
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295. Control Instruments
Bulletin 189 describes multi-record Electro strip chart potentiometer controllers. Avail with one or two set point indices, providing eit contact or proportional control or both. *Mi apolis-Honeywell Regulator Co.*

296. Copper Alloy Tubes
An extensively illustrated 32-page broch "Life Extension for Condenser Tubes", deals causes of corrosion and means of combating th as well as choice of materials for condenser tu *Revere Copper & Brass, Inc.*

297. Cutting Oils
Factual data on more than fifty typical me working jobs are presented in new 80-page edit of "Cutting and Grinding Facts". Also inclu descriptions of straight and emulsifiable cutt oils with convenient chart for correct use. *Oil Co.*

298. Dry Cooler
Bulletin DC-50 illustrates complete line DriCoolers in a wide range of capacities and des for specific cooling jobs. *Marley Co.*

299. Ductile Iron
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300. Fasteners
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303. Furnace Controls
Information available on Speedomax potentiometer instruments for simple, economical and dependable temperature control. *Leeds & Northrup Co.*

WHAT'S NEW
IN MANUFACTURERS' LITERAT

304. Furnaces
High temperature furnaces for temperatures up to 2000°F are described in leaflet. *Carl-Mayer Corp.*

305. Furnaces
New bulletin 84P describes eight sizes in gas or electric models as well as complete line of conveyorized and batch or pot-type furnaces. *Despatch Oven Co.*

306. Furnaces
New and comprehensive color-illustrated bulletin, "Surface Heating and Heat Treating Furnaces for Defense Production", covers heating for forging as well as heat treatments to develop the required properties for the production of all kinds of ordnance material. *Surface Combustion Corp.*

307. Furnaces
Bulletin T-1420 illustrates and describes Lindberg LI-25 induction heating unit. A ruggedly constructed vacuum-tube type of unit for hard working production-line jobs. Ideal for hardening, brazing and soldering annealing and other induction heating applications. *Lindberg Engineering Co.*

308. Furnaces, High Temperature
Fully descriptive brochures on research and production furnaces for annealing, brazing, and routine heat treating problems. *Harper Electric Furnace Co.*

309. Furnaces, Retort
Bulletin 412 R describes revolving retort furnaces for annealing, hardening or drawing metal pieces. Gas or oil-fired furnaces available with radiant tubes, if desired, and provided with atmosphere protection. *W. S. Rockwell Co.*

310. Gauges
32-page bulletin on series 500 line of recording gauges. Information is given on pressure gauges for ranges from 0 to 2 inches of water to 0 to 10,000 pounds per square inch, vacuum gauges, low-range draft and pressure gauges, barometers and absolute pressure gauges. *Bristol Co.*

311. Grinding Wheels
New 64-page catalog of mounted wheels for portable grinding tools. Includes recommendations for specific jobs. *Chicago Wheel & Mfg. Co.*

312. Hardening Machine
Booklet B-5259 gives detailed operational data on new radio-frequency gear-hardening machine, the Inductall. Versatility in handling spur gears, cluster gears and shafts for either through or contour hardening made possible by use of single-spindle type of feed. Also includes diagrams for power and water requirements for installing two or more machines. *Westinghouse Electric Corp.*

313. Hardness Tester
Bulletin ET 12 gives description of the new Ernst portable hardness tester for quick, accurate, direct readings without reference to conversion scales or calculations. *Newage International, Inc.*

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314. Hardness Testers
Bulletin DH-114 contains full information on Tukon hardness testers for use in research and industrial testing of metallic and nonmetallic materials. Also included is bulletin DH-7, giving experiences in various fields. *Wilson Mechanical Instrument Co.*

315. Heat Treating
Bulletin 820 gives detailed description with complete specifications on various size automatic quenching tanks for use with continuous heat treating equipment. *American Gas Furnace Co.*

316. Heat Treating
The Ajax salt bath brazing process is fully described in bulletin 124. Also shows how it is possible to substitute brass for copper and develop joints of adequate strength for most steel assemblies by this brazing method. *Ajax Electric Co.*

317. Heat Treating
Pressed steel lightweight sheet alloy heat treating units furnished in any size, design or specification. Write for full information on this. *The Pressed Steel Co.*

318. Heavy-Duty Forgings
16-page booklet on "Heavy-Duty Forgings", profusely illustrated, shows forgings of all sizes in every phase of development from ingot to finished product. *A. Finkl & Sons Co.*

319. High Speed Steels
New booklet, "Why Desegatized", shows how these hi-carbon hi-chrome steels help to cut production costs with thorough carbide distribution providing extra toughness and strength. *Latrobe Electric Steel Co.*

320. High-Temperature Testing
For precise hi-temperature testing send for illustrated technical folder on Marshall equipment. *L. H. Marshall Co.*

321. Hi-Temperature Alloys
New edition of "Haynes Alloys for High-Temperature Service" summarizes all available data on 10 super-alloys and lists physical and mechanical properties of two newly developed alloys. *Haynes Stellite Div.*

322. Immersion Heating
Bulletin IE-11 gives complete details on how new immersion pots save time and money in melting soft metals. High thermal efficiency for both large and small units provides rapid heat recovery in one-third the time. *C. M. Kemp Mfg. Co.*

323. Materials Handling Reprint
"Aluminum in Materials Handling" — a collection of seven articles on how the lightweight metal saves manpower and effects other economies in modern handling equipment. Prepared in pocket-size booklet form. *Aluminum Association.*

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WHAT'S NEW

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324. Mercury Cathode

Bulletin 220-1 describes completely new magnetic mercury cathode Dyna-Cath and shows how it permits economical and high speed separation of iron in determination of aluminum in steel. Also Methods Manual 260-1. *Eberbach & Son Co.*

325. Metal Cleaning

New service bulletin, "Heavy-Duty Alkaline Cleaning of Ferrous Metals", illustrates and describes in detail approved methods for alkaline soak tank cleaning, spray cleaning, electrolytic, barrel and steam gun cleaning. *Pennsylvania Salt Mfg. Co.*

326. Metal Cutting

New 64-page catalog gives prices and describes complete line of rotary files, burs, metalworking saws and other products. *Martindale Electric Co.*

327. Metal-Forming Lubrication

New bulletin 427 gives full details on use of colloidal graphite as a parting compound. Many specific applications show how this unique lubricant is unaffected by heat up to 3500°F. *Acheson Colloids Corp.*

328. Metallizing Process

New 20-page bulletin on the Mogul metallizing gun is fully illustrated and tells how this process aids in fighting corrosion, rebuilding worn parts, and reclaiming mis-machined castings. *Metallizing Co. of America.*

329. Metallurgical Microscope

For examination of opaque objects, polished metal specimens, similar materials, the Tri-Vert Illuminator (see catalog E-223) provides bright field, dark field or polarized light. *Bausch & Lomb Optical Co.*

330. Metal Spinning

New Spincraft data book — a valuable reference bulletin that illustrates lower costs made possible through pioneering developments in working of metals. *Spincraft, Inc.*

331. Microcasting

New color-illustrated folder, "Microcast Case Histories", describes microcasting applications for both industrial and defense requirements. *Austenal Laboratories, Inc.*

332. Mold Dryers

Bulletin 703 furnishes complete details on recirculating-air portable mold dryers designed for gas, oil or electric heat. Provide fast, uniform drying of pit molds or flask work too large for mold ovens. *Foundry Equipment Co.*

333. Oil Quenching

New folder available on oil quenching without distortion, using hot oil at temperatures up to 350°F, without undue thickening or oxidation. *E. F. Houghton & Co.*

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METAL PROGRESS
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April, 1951

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334. **Oils, Cutting**
For the right combination to suit your specific requirements, send for your copy of "Cutting Fluid Facts". *D. A. Stuart Oil Co.*

335. **Parts, Baskets**
Baskets designed for your individual needs in handling parts. All types of trays, fixtures, retorts and carburizing boxes are described in catalog 16. *Stanwood Corp.*

336. **Plating and Finishing**
New catalog of "Buffing & Polishing Compositions" contains wealth of valuable information on finishing. Illustrated with charts showing compositions to use on all types of metal from aluminum to zinc. *Lasalco, Inc.*

337. **Potentiometer, Portable**
Bulletins 270 and 270-A describe portable potentiometers in a selection of ranges up to 1.6 volts. *Rubicon Co.*

338. **Precision Castings**
4-page folder describes intricate precision castings produced centrifugally by "Lost-Wax" process to insure maximum physical properties from a variety of casting alloys. Advantages clearly illustrated by outlines of operations before and after. *Jelrus Co.*

339. **Presses**
New 12-page bulletin describes latest hydraulic presses for deep-drawing, forging, die straightening, coining, and shell-nosing. Also includes photos of actual installations. *Hydraulic Press Mfg. Co.*

340. **Protection for Aluminum**
New folder on the Alodizing process for applying phosphate coatings on aluminum parts and products. *American Chemical Paint Co.*

341. **Quenching Oil**
New technical bulletin F8 describes triple-action quenching oil. Accelerators provide deeper hardening and reduced distortion. *Park Chemical Co.*

342. **Recorders**
Bulletin C2-2 describes Capacilog line of electronically operated strip chart recorders. Also lists model numbers and specifications and explains how Direct Deflection, Wheatstone Bridge Circuit and Pneumatic Control types of systems are applied to Capacilogs. *Wheelco Instruments Co.*

343. **Refractory**
New 4-page illustrated folder, "JM-3000 Insulating Fire Brick", presents economic advantages, industrial applications and refractory properties of this product, for sustained use at 3000°F. *Johns-Manville.*

344. **Refractory**
4-page illustrated bulletin discusses properties and applications of Sillimanite Hydrocast, a mullite-base, castable refractory for use at temperatures up to 3000°F. *Chas. Taylor & Sons Co.*

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345. **Salt Baths**
Technical data sheets now available on two new carburizing compounds, barium-base materials for use in liquid bath carburizing. One is a briquetted mixture, relatively high in sodium cyanide and used to control cyanide concentration in operating baths. The other is a granular mixture used for the original fusion and to replace drag-out losses. *American Cyanamid Co.*

346. **Specimen Polishing with Diamond Compound**
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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

324. Mercury Cathode

Bulletin 220-1 describes completely new magnetic mercury cathode Dyna-Cath and shows how it permits economical and high speed separation of iron in determination of aluminum in steel. Also Methods Manual 260-1. *Eberbach & Son Co.*

325. Metal Cleaning

New service bulletin, "Heavy-Duty Alkaline Cleaning of Ferrous Metals", illustrates and describes in detail approved methods for alkaline soak tank cleaning, spray cleaning, electrolytic, barrel and steam gun cleaning. *Pennsylvania Salt Mfg. Co.*

326. Metal Cutting

New 64-page catalog gives prices and describes complete line of rotary files, burs, metalworking saws and other products. *Martindale Electric Co.*

327. Metal-Forming Lubrication

New bulletin 427 gives full details on use of colloidal graphite as a parting compound. Many specific applications show how this unique lubricant is unaffected by heat up to 3500°F. *Acheson Colloids Corp.*

328. Metallizing Process

New 20-page bulletin on the Mogul metallizing gun is fully illustrated and tells how this process aids in fighting corrosion, rebuilding worn parts, and reclaiming mis-machined castings. *Metallizing Co. of America.*

329. Metallurgical Microscope

For examination of opaque objects, polished metal specimens, similar materials, the Tri-Vert Illuminator (see catalog E-223) provides bright field, dark field or polarized light. *Bausch & Lomb Optical Co.*

330. Metal Spinning

New Spincraft data book — a valuable reference bulletin that illustrates lower costs made possible through pioneering developments in working of metals. *Spincraft, Inc.*

331. Microcasting

New color-illustrated folder, "Microcast Case Histories", describes microcasting applications for both industrial and defense requirements. *Austenal Laboratories, Inc.*

332. Mold Dryers

Bulletin 703 furnishes complete details on recirculating-air portable mold dryers designed for gas, oil or electric heat. Provide fast, uniform drying of pit molds or flask work too large for mold ovens. *Foundry Equipment Co.*

333. Oil Quenching

New folder available on oil quenching without distortion, using hot oil at temperatures up to 350°F, without undue thickening or oxidation. *E. F. Houghton & Co.*

334. Oils, Cutting

For the right combination to suit your specific requirements, send for your copy of "Cutting Fluid Facts". *D. A. Stuart Oil Co.*

335. Parts, Baskets

Baskets designed for your individual needs in handling parts. All types of trays, fixtures, retorts and carburizing boxes are described in catalog 16. *Stanwood Corp.*

336. Plating and Finishing

New catalog of "Buffing & Polishing Compositions" contains wealth of valuable information on finishing. Illustrated with charts showing compositions to use on all types of metal from aluminum to zinc. *Lasalco, Inc.*

337. Potentiometer, Portable

Bulletins 270 and 270-A describe portable potentiometers in a selection of ranges up to 1.6 volts. *Rubicon Co.*

338. Precision Castings

4-page folder describes intricate precision castings produced centrifugally by "Lost-Wax" process to insure maximum physical properties from a variety of casting alloys. Advantages clearly illustrated by outlines of operations before and after. *Jelrus Co.*

339. Presses

New 12-page bulletin describes latest hydraulic presses for deep-drawing, forging, die straightening, coining, and shell-nosing. Also includes photos of actual installations. *Hydraulic Press Mfg. Co.*

340. Protection for Aluminum

New folder on the Alodizing process for applying phosphate coatings on aluminum parts and products. *American Chemical Paint Co.*

341. Quenching Oil

New technical bulletin F8 describes triple-action quenching oil. Accelerators provide deeper hardening and reduced distortion. *Park Chemical Co.*

342. Recorders

Bulletin C2-2 describes Capacilog line of electronically operated strip chart recorders. Also lists model numbers and specifications and explains how Direct Deflection, Wheatstone Bridge Circuit and Pneumatic Control types of systems are applied to Capacilogs. *Wheelco Instruments Co.*

343. Refractory

New 4-page illustrated folder, "JM-3000 Insulating Fire Brick", presents economic advantages, industrial applications and refractory properties of this product, for sustained use at 3000°F. *Johns-Manville.*

344. Refractory

4-page illustrated bulletin discusses properties and applications of Sillimanite Hydrocast, a mullite-base, castable refractory for use at temperatures up to 3000°F. *Chas. Taylor & Sons Co.*

345. Salt Baths

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[• If mailed from countries outside the United States, proper amount of postage stamps must be affixed for returning card]

METAL PROGRESS

7301 Euclid Avenue, Cleveland 3, Ohio

April, 1951

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Please have literature circled at the left sent to me.

Name ______________________ **Title** ______________

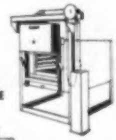
Company ______________________________

Products Manufactured ______________________________

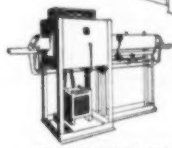
Address ______________________________

City and State ______________________________

Postcard must be mailed prior to July 1, 1951—
Students should write direct to manufacturers.



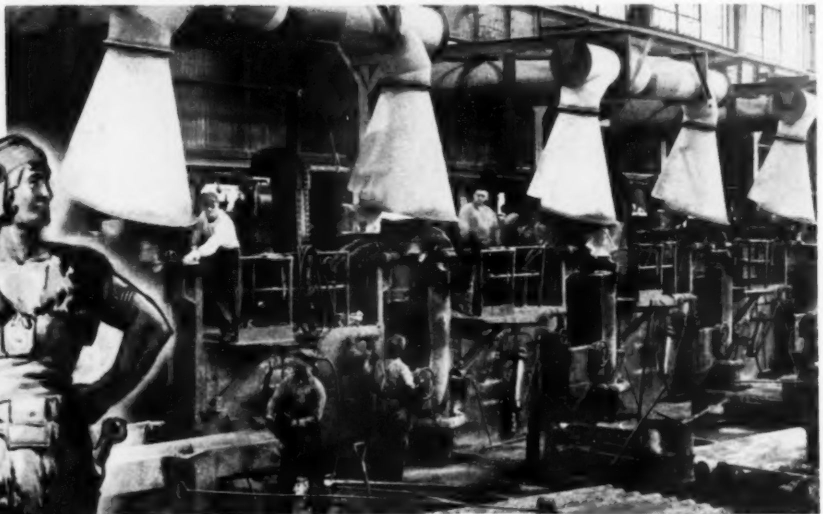
TYPE FR-251 BOX FURNACE



TYPE FK BRAZING FURNACE

TYPE OR-104 POT FURNACE

Titan Metal Manufacturing Company produces a wide range of brass billets for extrusion purposes, made from 80 different alloys, in this battery of induction melting furnaces lined with Taylor Sillimanite.



TAYLOR Sillimanite teams with Titan

for cost-cutting production of brass and bronze

The Titan Metal Manufacturing Company, Bellefonte, Pennsylvania, major producer of first-quality brass and bronze products, has standardized on Taylor Sillimanite No. 217 "Ajax" Ramming Mix for forming the secondary blocks of their Ajax-Wyatt induction furnaces. Comparative tests have proved to Titan that Taylor Sillimanite (TASIL) gives longer lining life and increased furnace production. A recent annual average for all of their TASIL linings amounted to 4,000,000 pounds of yellow brass per lining.

You'll hear the same story whenever comparative tests are made. TASIL No. 217 Ramming Mix was designed solely for forming the crucible section and secondary blocks of low frequency induction furnaces melting yellow brass and high copper alloys. It is known for low permeability—high refractoriness—good ramming properties and high density. Test TASIL No. 217 Ramming Mix in your plant.

Refractorers to industry since 1864.

Exclusive Agents in Canada:
REFRACTORIES ENGINEERING AND SUPPLIES, LTD.
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TAYLOR SILLIMANITE

The CHAS. TAYLOR SONS Co.

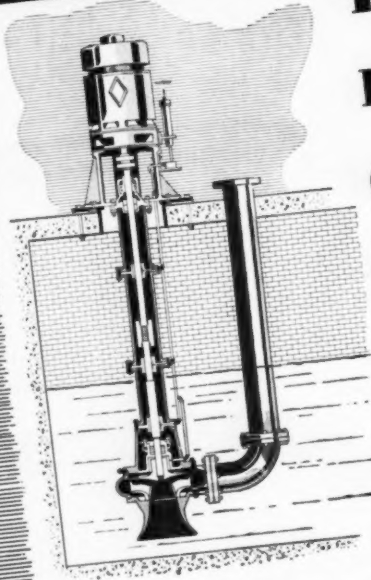
REG. U. S. PAT. OFF.

MANUFACTURERS OF REFRACTORIES • CINCINNATI • OHIO • U. S. A.


MAKE A TON OF SHEET STEEL
GO FARTHER
Specify—
N·A·X
HIGH-TENSILE STEEL
... And
"MAKE YOUR PRODUCT
LAST LONGER"

Unretouched photographs of precision parts quenched from a carbo-nitriding furnace in Park Triple A Quench Oil. From left to right are parts quenched the first day, 30 days later, 60 days later, and 90 days later. Bright and clean after over 3 months use with no indication of reduction of surface cleanliness.

PUMP MANUFACTURERS SPECIFY BRONZE



Because of Its Resistance to Corrosion... Pressure Tightness and Anti-Frictional Characteristics

Bronze pumps are used in every phase of modern civilization. Pumps are required to convey corrosive liquids in industry, sea water in our navy's ships, water in fire extinguishing equipment and waste in sewage disposal systems.

Pressure tightness, resistance to corrosion, strength, ductility and anti-frictional characteristics are some of the qualities required of pump materials.

Wherever liquids are used ... *in home or in industry* ... pumps with essential Bronze parts play a vital role.

Specify—LAVIN NON-FERROUS INGOT—*Quality*

R. LAVIN & SONS, INC.

Refiners of Brass, Bronze and Aluminum

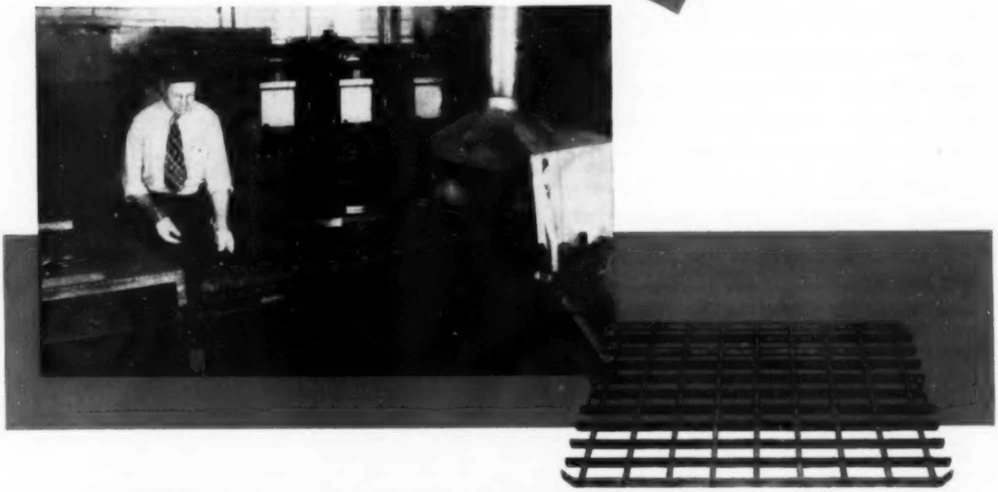
3426 SOUTH KEDZIE AVENUE · CHICAGO 23, ILLINOIS

REPRESENTATIVES IN PRINCIPAL CITIES

ROLOCK

HEAT AND CORROSION RESISTANT

FABRICATED ALLOYS



ARTICULATED TRAYS *for highest resistance to* WARPING . . . UNDER EXTREME TEMPERATURES

The photograph above shows an installation of furnace trays built by Rolock for National Stamping Company, Detroit, Michigan. They are used in a General Electric roller hearth furnace operating at 2050 degrees on copper brazing and at 1600 to 1800 degrees on bright annealing.

Flat bar construction of the 60 lb. tray with bent outer bars, to avoid catching on roll guides, gives optimum performance with loads 100 lbs. and over. Hot rolled bars prevent scoring of furnace rolls . . . flexible construction eliminates warping and cracking. Handles at ends also serve to index cover screen for small parts. The carefully checked performance proves the importance of job-engineered design for a specific condition.

If you are experiencing tray troubles . . . short service life, cracking, warping . . . ask Rolock engineers for recommendations. We can cut your heat-hour costs and improve processing. Catalog and Bulletin on request.

Offices in: PHILADELPHIA • CLEVELAND • DETROIT • HOUSTON • INDIANAPOLIS • CHICAGO • ST. LOUIS • LOS ANGELES • MINNEAPOLIS

ROLOCK INC. • 1222 KINGS HIGHWAY, FAIRFIELD, CONN.

JOB-ENGINEERED for better work
Easier Operation, Lower Cost

2RL51

Republic Metallurgical Service

helps leading bearing producer *save 30%* IN HEAT TREATMENT COSTS

When you can take a top-quality precision bearing, improve the quality still further—*and cut production costs in the process*—there's sure to be an interesting story involved.

In this case, it's the story of many months of close cooperation between the metallurgical staffs of a leading roller-bearing producer and Republic Steel. It's a story that may be summarized like this:

Having determined that no appreciable advantages could be obtained from a change in alloy steel analyses, Republic's Field Metallurgist recommended a change in heat treatment cycle. The change was made. After a thorough testing period, the following benefits were noted:

1. **Furnace time required for carburizing—substantially reduced.**
2. **Re-heat treat—almost completely eliminated.**
3. **Parts distortion resulting from heat treat—also reduced.**

As a result, overall heat treatment costs were reduced by approximately 30% ... grinding time of carburized parts was effectively lessened ... bearing quality was further improved.

Perhaps you, too, are using the *right* analysis of alloy steel, but could profit through more efficient processing of that steel.

Republic—world's largest producer of alloy and stainless steels—offers you the *confidential* services of its 3-Dimensional Metallurgical Service without cost or obligation. Write, wire or phone.

REPUBLIC STEEL CORPORATION

Alloy Steel Division • Massillon, Ohio

GENERAL OFFICES • CLEVELAND 1, OHIO

Export Dept.: Chrysler Bldg., New York 17, N.Y.

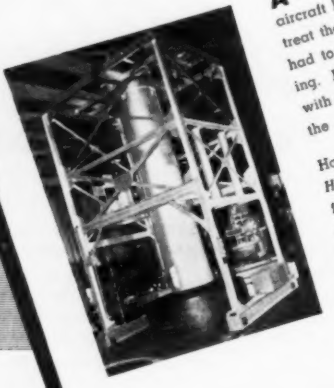
LAB MILL FIELD
3-DIMENSION Metallurgical Service

...combines the extensive experience and coordinated abilities of Republic's *Field, Mill* and *Laboratory* Metallurgists with the knowledge and skills of your own engineers. It has helped guide users of Alloy Steels in countless industries to the correct steel and its most efficient usage. IT CAN DO THE SAME FOR YOU.

Republic ALLOY STEELS

REPUBLIC STEEL

Other Republic Products Include Carbon and Stainless Steels—Sheets, Strip, Plates, Pipe, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing



A concern making landing gear for aircraft had a hard time trying to heat treat them. A medium-low carbon steel had to be used to permit proper welding. But despite a special tank set-up with movable hood, they couldn't meet the required physicals.

Houghton was called in. We supplied Houghto-Quench for the tank — that faster quenching oil that has so often meant the difference between exceeding requirements and failure in the heat treat. Result: high tensile, high yield, high hardness.

The Aircraft Landing Gear That Would Not Meet "Specs"

For speedier, more dependable quenching, use —

HOUGHTO-QUENCH

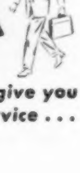
● Your quenching layout may be 100% efficient . . . or it may need checking. Your steel may be right for the job, or getting leaner in alloy content. In either case, the wrong kind of quenching oil can jeopardize the heat-treating results you need today.

With Houghto-Quench, formulated in Houghton laboratories *solely* for quenching, you'll have no worries on that score. Here is a stable oil that absorbs heat faster. It maintains uniform quenching speed regardless of bath temperature. It is ideal for speedy deep hardening.

Get the complete story on Houghto-Quench, and how it is backed by an engineering service that goes right down the line for you . . . helps solve the tough quenching problems you may have today with low-alloy steels. See the Houghton Man, or write direct to E. F. Houghton & Co., Philadelphia 33, Pa.

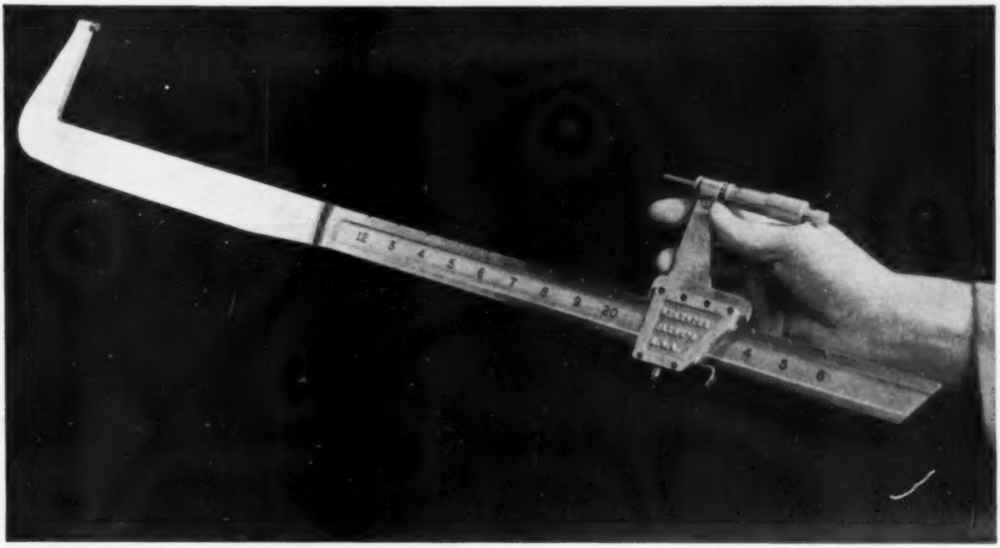
HOUGHTO-QUENCH...a product of E. F. HOUGHTON & CO.

PHILADELPHIA · CHICAGO · DETROIT · SAN FRANCISCO



Ready to give you on-the-job service . . .

How GRAPH-MO steel made a micrometer measure up



PRECISION'S the thing at the Lester Micrometer Company, Cleveland, Ohio, and a good example of it is their V-notch Adjustable Micrometer. The extreme accuracy of this instrument depends on the precise spacing of the V-notches. And the micrometer spacer must maintain a certain accuracy between the anvils. Finding a steel that would permit and maintain this precision posed a problem. The right steel for this job would have to: 1. retain its initial accuracy over a long period of years, 2. give minimum distortion from heat treating, 3. machine easily and 4. assure excellent welded characteristics for strength.

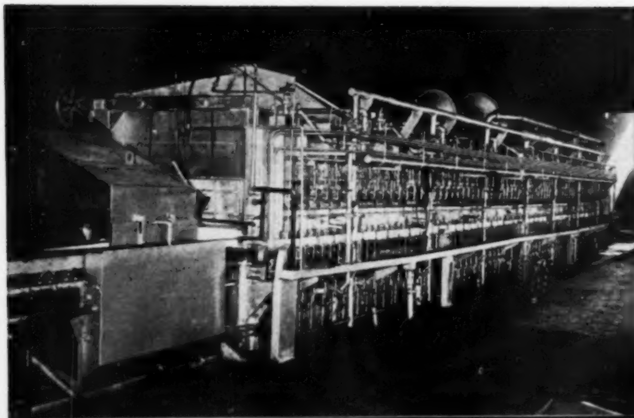
After experimenting with other steels, the engineers found the answer in Graph-Mo steel. Graph-Mo did not change size in aging, did not warp or crack during heat treating, machined easily and allowed ductile welds that did not develop cracks under shock loading.

Because Graph-Mo contains free graphite, it machines fast and easily to close tolerances. It hardens uniformly with minimum distortion and gives an extremely fine finish after polishing. And due to diamond-hard carbides in the structure, it offers unusually stubborn resistance to wear and abrasion.

Graph-Mo is one of four Timken® graphitic tool steels widely used in gauges, dies, machine parts and other applications. For further information, write for the enlarged 9th edition of the Timken Graphitic Steel Data Book. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

Specialists in alloy steel—including hot rolled and cold finished alloy steel bars—a complete range of stainless, graphitic and standard tool analyses—and alloy and stainless seamless steel tubing.



GAS MACHINERY COMPANY

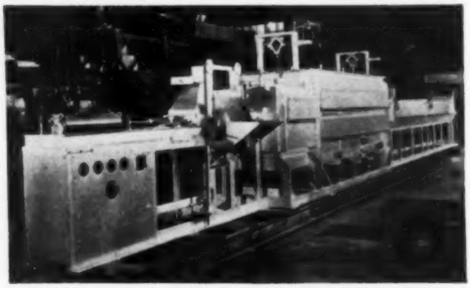
This roller hearth type furnace for annealing stainless steel sheet is equipped with CARBOFRAX silicon carbide rolls. Consequently, the hearth stays straight, the rolls last longer, and there is less marking and pick-up than with metal rolls. The furnace is gas fired to 2450°F with CARBOFRAX radiant tubes located above and below the hearth. CARBOFRAX radiant tubes provide high heat conductivity, excellent refractoriness and the necessary gas tightness.

Super Refractories by CARBORUNDUM are used in almost every heat-treating furnace

Are your furnace floors tough enough to withstand heavy abrasion at high temperatures? Does your hearth or muffle transfer heat as fast as it should—i.e., so that you get the maximum number of heats? Do your supports keep the floor level under heavy loads? Do your burner ports or other furnace parts crack or spall?

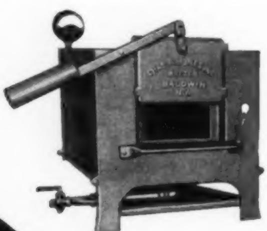
As so many furnace manufacturers know, the answer to these problems lies in a well balanced team of heavy-duty, special purpose refractories—Super Refractories by CARBORUNDUM.

Our 40-page booklet, "Super Refractories for Heat Treatment Furnaces" gives specific recommendations. May we send you a copy?



HARPER ELECTRIC FURNACE CORPORATION

This electrically heated pusher-type furnace is used for sintering powdered metal parts in special atmospheres at 2100°F. It uses an ALFRAX K electrically fused alumina hearth with MULLFRAX electric furnace mullite roof and lintels. The ALFRAX K hearth supports an inconel muffle and is used because of its thermal conductivity, good hot strength and long life. The MULLFRAX material is used for its exceptional strength at high temperatures.



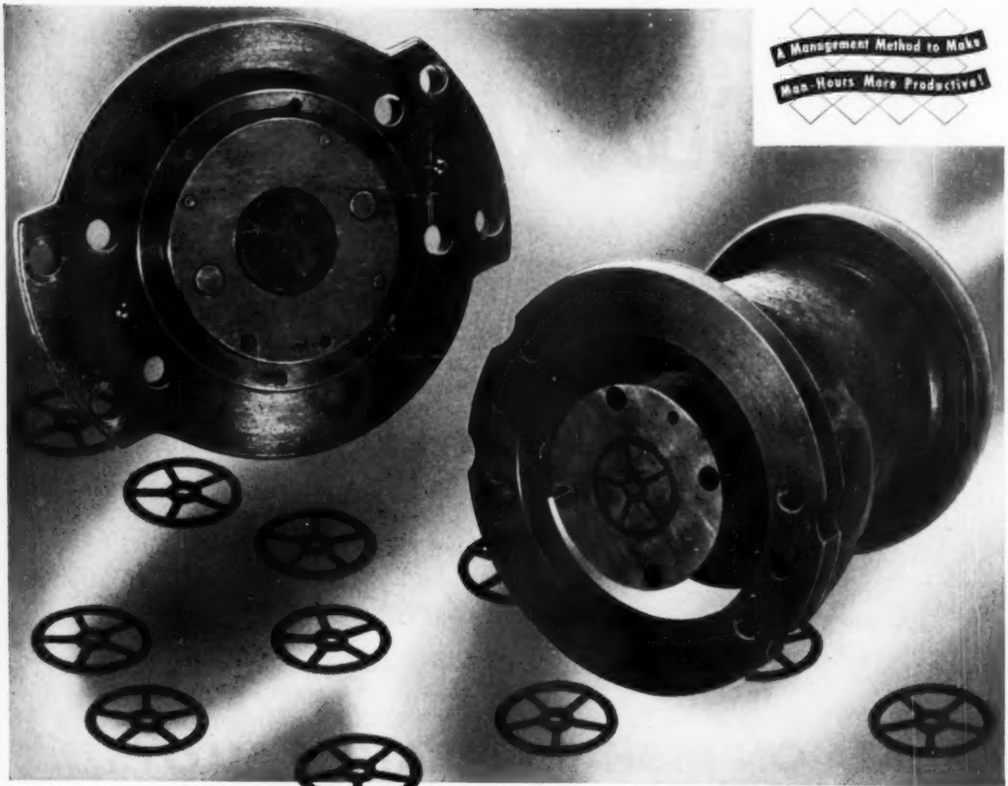
CHARLES A. HONES, INCORPORATED

This bench type oven furnace is gas fired. It is designed to heat up to 1400°F in 15 minutes and to 2000°F in 50 minutes without the use of gas boosters, blowers, etc. Here, the high heat conductivity of the CARBOFRAX hearth is of real value—as is its extreme resistance to both mechanical abrasion and to heat shock.

CARBORUNDUM TRADE MARK

THE CARBORUNDUM COMPANY

Dept. C-41, Refractories Div. Perth Amboy, N. J.



Why Not Gear Up For Today's Production This Way?

For 11 years this Stentor blanking die and punch gave trouble-free performance, averaging 100,000 gears per grind. This record enabled management and production to avoid production delays by keeping machines operating with fewer shutdowns for resharpening. The precision gears, 120 teeth/90 pitch, are made from 24 ga., ¼-hard brass. In heat treatment the die moved only .0005″ on the maximum diameter of the gear.

It wasn't a happy coincidence that the tool and die steel was perfectly suited to put production from the tools on a smooth, trouble-free basis. It was planned that way—with the help of the Carpenter Matched Set Method. For the Method not only enabled this plant to eliminate costly experimentation in selecting the right steel, but enabled management to forecast output in advance because they could count on the tools to produce the parts *on time*.

Used in hundreds of plants, the Method offers far more than simplified tool steel selection. It makes machine operators more productive. It enables your plant to carry lower tool steel inventories. It makes heat treating easier, simplifies toolroom and production procedures. What's more, it is amazingly easy to apply. No extra cost or bother. To discover what it can do for you, ask for the new booklet "How to Get Better Tool and Die Performance". THE CARPENTER STEEL CO., 133 W. Bern St., Reading, Pa.

Export Department: The Carpenter Steel Company, Reading, Pa. "CARSTEELCO".

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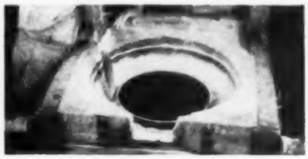

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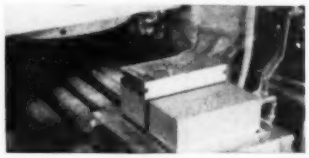

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Cover by Gene Mogish

Technical Articles

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Abstracts of Important Articles

As Observed by
The Editor
of Metal Progress

Metallurgical Activities at Aberdeen Proving Ground

ABERDEEN Proving Ground and Edgewood Arsenal (officially, the Army Chemical Center at Edgewood, Md.) are two long-established Army installations on the west shore of Chesapeake Bay about 30 miles north of Baltimore. The map boundaries of the Proving Ground include 74,693 acres, but deep indentations from the bay and an eastern boundary well off-shore leave only 37,959 acres of dry land. The word "dry" is not too accurate, for there is much swamp and marsh; the highest "hill" on the reservation is 315 ft. above sea level. Much of the woods that originally covered the site have been cut away, so the area is reasonably well fitted for the testing of equipment in flat country. The Churchville Test Range, used in tank development and testing, is really rugged — any kind of terrain except desert and arctic. Nature has provided many of the requirements except arctic weather and craggy mountains; artificial substitutes are cold rooms and man-made obstacles. The length of the longest firing range on land is 27,500 yd. (15½ miles); longer range guns can fire out into a protected area in Chesapeake Bay.

The name "Proving Ground" is likely to give a misconception of the mission of the establishment. Primarily it is a research and development agency, and the largest fraction of its equipment and personnel are devoted to unspectacular but precise studies of the motion of guns, powder, projectiles, bombs and rockets in all their aspects, so securing a rational basis for design. Design and development of ordnance are logically the next steps. Adequate instrumentation for these studies also requires much attention. This meticulous and extensive preliminary work is overpowered — especially in the eyes and ears of an occasional visitor at a demonstration — by the big bang with which the completed ordnance speaks!

Of course "proving" is also an important function — a function that can be appreciated by the ordinary citizen since American automobile companies have made much of their own proving grounds in promotional advertising. Speaking broadly, this consists primarily of putting samples of new ordnance equipment or components, both prototypes and production models, through their paces under severe conditions and precise observation, to find out whether they perform as expected; if not, to discover why, so corrections can be made.

"Ordnance" in that last sentence includes small arms and grenades, artillery (howitzers, anti-aircraft and field guns), short-range weapons (bazookas, mortars and rocket launchers) and ammunition for all such weapons, as well as bombs, mines and demolition charges, armored carriages, vehicles and tanks, and automotive equipment of all sorts. Also radar for detection and tracking, and automatic fire control. "Ordnance" thus includes the fighting equipment of the infantryman, his armored support and his transport — about everything he needs except food and clothing (the responsibility of the Quartermaster Corps). Obviously the scope of its functions has been enormously increased since World War I days when the foot soldier had a rifle and bayonet and the artilleryman a horse-drawn 3-in. cannon!

As indicated above, actual field testing is

preceded by work in well-equipped laboratories for chemical investigations, for physical measurements of all sorts — especially at high speed — and for the testing of materials. As of today these activities require the services of 8000 officers and enlisted men and 4000 civilians. (A wide area contains in stand-by condition housing and structures devoted in the last war to the training of maintenance troops; this activity increased the post's population to about 32,400 souls.) A department of major interest and importance is the museum containing many examples of enemy equipment. Additions are currently being made from Korea. The items are not merely stored, they are proof tested, then dismantled and scrutinized for design and quality of materials and workmanship.

Through the courtesy of Major General E. E. MacMorland, commanding general, the Editor recently spent an interesting day with Charles McKnight ⊕, chief engineer of the Arms and Ammunition Division. In what follows an attempt will be made to outline some of the present activities at Aberdeen of metallurgical interest without getting off-limits into secrecy, and to supplement observations at the last Ordnance Association meeting, briefly presented in "Critical Points" in last November's issue of *Metal Progress*.

Gun Tubes

The rifled gun tube is an ordnance part that has been under close and continuous study for at least 80 years. It is an expensive forging, centrifugal casting, or pierced and upset tube, intricately machined to close tolerances. It has a relatively short service life; propellent gases are considerably hotter than the melting point of steel, so each round carries out with it a little metal from the bore. Only so many rounds and the accuracy starts to deteriorate. Nothing much can be done to the steel to slow down this erosion — most intense when high-velocity armor-piercing shot are fired, much less with antipersonnel rounds. All the time the tube must be tough, tough even in the arctic. (*All ordnance items are required to function normally in the temperature range of* −65° F. to +165° F.)

Through the years, improvements in gun steel, design of breech, bore, and projectile, and nature of propellent powder have cooperated to lighten materially the weight of the tube — important not only to conserve material but to increase portability. By 1940 the American arsenals were pretty proud of the result. Here's where Aberdeen's museum stepped in! Captured foreign guns, giving comparative performance, were often found to be considerably lighter than ours! Re-examination indicated that the classical theories of gun design were generously inaccurate.

Tubes are now lighter, yet amply safe.

Still, erosion is with us. Two palliatives are practical: 1. Arrange the mount so barrels can be replaced easily; 2. Use replaceable liners in the larger calibers. However, these are palliatives; a real cure runs into shortages of strategic metals. High cobalt-chromium-molybdenum-tungsten alloys are fine, but there is simply not enough of these metals available for the hundreds of thousands of guns that must be made. Active work therefore still continues on liners or coatings of available metals other than steel. (Remember how Harry Brearley discovered stainless during an unsuccessful effort to raise the melting point of gun steel by adding chromium?) Some really good refractory metals or mixtures are too hard for machining so they have to be shaped precisely by "electro-forming" or powder metallurgical methods. These operations, plus the cost of the somewhat rare metals themselves, will confine their nearby use to such items as high-speed machine guns, firing up to 20

240-Mm. Howitzer Motor Carriage at High Speed, Cross Country, at Aberdeen Proving Ground's Churchville Test Range, Which Is a Really Rugged Course for Any Vehicle

rounds per sec., or long-range automatic anti-aircraft pieces.

One trouble that cropped up more recently concerns muzzle brakes. A muzzle brake is a steel casting fitted to the barrel's end, having internal vanes that catch and divert some of the propellent gases as they rush forward, thus partially checking the recoil. A gun with a good muzzle brake can be designed with a lighter recoil mechanism and mount. When a muzzle brake fails, subsequent firing overloads the entire mount and slows down the firing rate, for the aim must be corrected after each round. Design stresses are not excessive for the steel casting, and failures are so closely bound up with internal segregation and unsoundness that it seems almost necessary to specify a 100% radiographic test — a rather expensive price to pay for slack work in the steel foundry.

Armor

Armor itself, of course, comes in for proof testing — all the way up from the laminated aluminum sheet and rayon cloth for body armor, through the light plate for armored vehicles and field gun shields, to the heavy castings used for tanks. Numberless proof tests indicate that a modification of the ancient "Krupp analysis" (chromium-nickel-molybdenum), soundly cast and adequately heat treated, is better than anything yet suggested. It possibly represents the limit in steel. "Soundly cast" is said advisedly. At Aberdeen is the opinion that armor takes on the character of its maker. Plates delivered by a steel plant which has modern equipment, staffed by men who are proud of an excellent record, are sure to perform excellently. In fact, every now and then a plate of this sort confounds the test and the testers by resisting completely an attack which, according to the book, should penetrate. Believe that such a plate is given the most microscopic examination!

Russian medium tanks of 1940 manufacture, despite a power plant of doubtful performance, had excellent Krupp-type armor and a very low silhouette. It was hard to hit and, when hit, hard to stop. By the war's end, the Russians had increased the gun from its original 76.2 mm. to a high velocity 85 mm. without doing much else. In other words, this tank now has maximum striking power for its over-all weight — a most desirable combination. Recent specimens from Korea examined by Aberdeen's museum staff carry quite inferior armor; it is a silico-manganese steel of much higher hardness than customary. This might mean that there is a shortage in desirable alloying elements (especially nickel) in Russia, or it might merely be that the Russians have given their little yellow brothers some stuff that is not nearly as good as their theorists predicted.

Lack of chromium, nickel and vanadium will hamper the making of good armor, as was amply demonstrated in World War II. Ballistically, the low-alloy "triple steels" were nothing to brag about in that particular service.

Projectiles

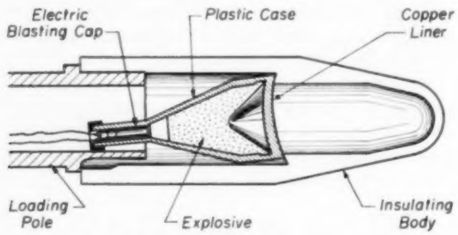
From armor to armor-piercing shot is no step at all; they've been improved, side by side, ever since the "Monitor" fought the "Merrimac". One present inquiry under way at Aberdeen is to find a satisfactory substitute for tungsten carbide. Naval projectiles first used a blunt-nosed cap of soft iron around the sharp end of a hardened steel projectile; on impact the cap held the hard, brittle point together so it would not shatter *before* it started to penetrate the armor. (Once started, the armor itself formed the sheath.) During the last war, sheathed

Soviet Tanks (T-34) With 85-Mm. Gun Captured in Korea, 1950

tungsten carbide was used most satisfactorily for cores of A.P. shot. But tungsten is so valuable for toolsteels and other critical uses that the search is now on for another material that is very hard (to penetrate) and has a high specific gravity (inertia to carry through).

Meanwhile the old-fashioned A.P. shot has been improved so that its performance on striking any type armor at high obliquity (50°, or more acutely) is phenomenal. (This is really good news, for the glacis plate on the Russian tank Joseph Stalin III is 55°, and something must be ready to get inside that thing.)

Another weapon for piercing armor is the well-known bazooka. Its projectile is a slow-speed rocket whose penetrating power is due to the "shaped charge". The striking end of the projectile is filled with high explosive having a conical cavity, large end forward. Explosion on contact causes a blast to converge from all sides into the axis, and this has nowhere to go except forward as a superheated stream of white-hot gas which neatly bores a hole into the obstruction — armor, concrete, or whatever. Present studies by the Arms and Ammunition Division at Aberdeen have to do with the penetrating power in relation to the shape of the cavity, the material which is used as its interior mold, and its wall thickness — with some attention to mass production of the rather difficult shapes that may be evolved.



Du Pont "Jet Tappers" for Openhearth Furnaces Use the Shaped Charge of the Bazooka to Drill a Neat Hole Through the Clay Which Plugs the Tap Hole

Several curious facts emerge from these studies. For example: High-speed photographs show that the shape-liner collapses into the form of an elongated bodkin and *follows* the gas stream. It apparently has little or no effect on the penetration — it either follows through the hole already made, or plasters itself along the sides of the hole, or some of both.

The object, of course, is not only to penetrate the armor, but to put through the hole enough fire or molten metal to derange completely whatever is on the other side. In this respect the bazooka shell — unless of rather large caliber — is not as destructive as two other devices. One is a bit of highly classified information; the other is the "napalm" bomb. Even a near-miss that isn't very near will cover the tank with viciously burning goo. The crew is probably smothered by oxygen depletion, since the motors stop and the heat developed is not enough to explode ammunition nor to char men's clothing or blister their faces.

One interesting byproduct of bazooka studies is an inquiry into what happens to the metal that originally filled the hole. First-hand you would say that it burned up, was pushed out ahead, or mushroomed backward. However, if an 8-in. block with a neat 1-in. bazooka hole is cut from the pierced armor, it weighs just about as much as a solid equivalent! Salvatore Uzzo ⊛, chief of the X-ray and Metallurgical section, is now studying a block that was accurately machined and gaged before penetration. While there is a little thickening near the hole, this is not enough to account for the metal that (by weight) remains.

It's always nice to think of turning swords into plowshares, and the bazooka's shaped charge gives us an interesting example. All too often in these days of recurrent wars, the military draws upon peacetime industry for its tools and equipment. However, the shaped charge, a purely military tool, is now utilized for drilling hard holes in quarrying and in underground mining, and for shooting oil wells. Most recently Du Pont has commercialized "jet tappers" for openhearths and blast furnaces. The accompanying illustration shows exactly what a shaped charge looks like to the X-ray; only 2 oz. of especially insensitive explosive will open a 1-in. hole through the hot tap-hole facing. (It will penetrate 6 in. of cold steel.)

In that same metallurgical laboratory were seen many samples of broken tank and automotive parts — most of them fatigue failures, and most of these blamed on sharp fillets or tool marks on surfaces taking maximum stress. Others are not so easily explained — even after sister equipment is plastered with strain gages leading to high-speed automatic recorders and operated in severe service. Much of the fascinating research on metal, in fact, at Aberdeen Proving Ground has to do with conditions that were unthought of or disregarded 50 years ago, such as excessively high impacts, endurance under frequent overloads, toughness at low temperatures, and surface conditions to resist erosion and scour. ⊖

High-Temperature Problems in Aircraft Jet Engines and Turbo-Superchargers

THIS PAPER was read before the Minneapolis Chapter, ⊕, with the object of presenting a metallurgist's viewpoint of some of the problems encountered in high-temperature metals during the development of aircraft jet engines and turbo-superchargers. Parts discussed will be the combustion chamber liner, the nozzle diaphragm partition, the turbine buckets, and the tail cone on the jet engine, and the nozzle box, the nozzle diaphragm, the turbine wheel, and turbine buckets on the turbo-supercharger. All designs and parts referred to are obsolete, but exhibit typical problems as to materials of construction. Since *design* plays such an important part in the performance of most machine parts, successful operation of a gas turbine (or almost any apparatus) depends on a compromise between design and material as well as availability and cost.

It is also intended that the reader not be left with the impression that aircraft gas turbines present more problems in their development than other types of engines — rather a somewhat different set of problems have been faced. Nevertheless, as in most aircraft application — particularly for the military — long engine life tends to be sacrificed for high performance. This trend is expected to continue, even though the available materials are substantially improved.

Those parts in jet engines and turbo-superchargers which operate above 1200° F. for some of their useful life are the limiting factors in setting periods of overhaul for this type of apparatus. This is true, not only because of the high temperature, but also because of the high stresses, both in rotating and stationary parts. High stresses in rotating parts come from high speeds of rotation, alternating loads, and changing thermal gradients; stationary parts are highly stressed primarily from thermal gradients and alternating loads.

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The engineer may design these high-temperature parts for an expected life of perhaps 1000 hr. and will include the margins of safety typical of aircraft equipment and bear the important point of weight conservation constantly in mind. If, however, a jet engine or turbo-supercharger part fails prematurely when in operation or on test, it is important to know the real cause or causes, so changes can be made to prevent reoccurrence. These causes can generally be assigned to poor control of material processing or inspection, to poor control of test conditions, or to design deficiencies.

First, to acquaint the reader with the expected operating temperature of the high-temperature parts in jet engine and turbo-supercharger, the following list is presented:

Jet Engine

Combustion liner — 900 to 1800° F.
Diaphragm partition — 900 to 1650° F.
Turbine wheel — 400 to 1200° F.
Turbine bucket — 1200 to 1500° F.
Tail cone — 900 to 1400° F.

Turbo-Supercharger

Nozzle box — 1200 to 1700° F.
Diaphragm — 900 to 1600° F.
Turbine wheel — 500 to 1200° F.
Turbine bucket — 1200 to 1500° F.

Combustion Chamber Liners have a maximum metal temperature normally on the order of 1800° F. However, there are occasional hotter spots in the chamber

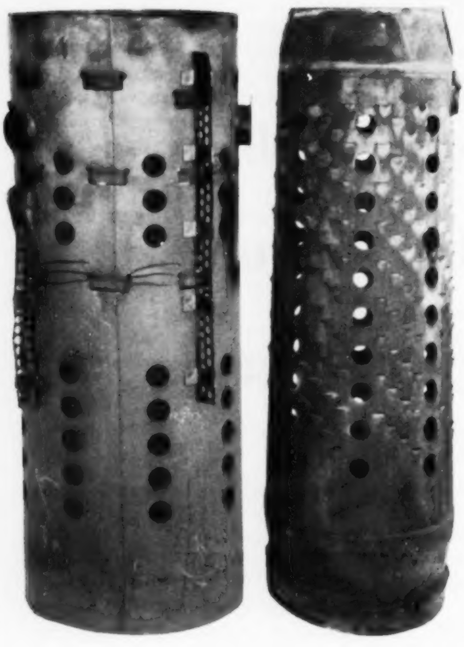


Fig. 1 — Obsolete Designs of Jet Engine Combustion Chamber Liners, About 1/5 Natural Size. Left, rolled Vitallium, cracked after 250 hr. on "endurance test schedule"; right, later design in Type 310 stainless after 300 hr. of engine test

liner due to poor fuel flow or pressure unbalance which can cause temperatures in excess of 2100° F. These hot spots are the direct cause of extreme thermal gradients and high thermal stresses, as well as so much distortion that portions may bulge into the flame passage (at 3000° F.) which quickly destroys a metal liner. Figure 1 (left) shows an obsolete liner which is considered failed after 250 hr. of engine operation on an "endurance test schedule". The other view in Fig. 1 is a more modern liner after 300 hr. on test, which shows no evidence of distress. (It should be noted that Vitallium sheet was never actually used in the production of General Electric's jet combustion chamber liners.)

The performance of various metals and alloys, when tested as combustion chambers in engines, appears to have a definite relation to the tensile strength of the sheet metal at about 1800° F. Performance (time) as a function of tensile strength at 1800° F. is shown in Fig. 2 for one set of engine tests. Increased ductility does not correlate with increased liner life; however, a certain minimum ductility is believed to be essential.

Alloys with increased thermal conductivity do not seem to be the direct solution to this problem, because neither Inconel-clad nickel nor stainless-clad copper has given exceptional life. Here again, the discrepancy is believed to be due to a lack of strength to resist buckling from stresses set up by thermal gradients. If all other things were equal, however, it is believed that the material with higher conductivity would give the longer life. Most of the alloys which have been tested have about the same thermal conductivity at 1800° F., although at room temperature they differ substantially. (See Fig. 3.)

Ceramic coatings on the metal liner — another approach to a solution of this problem — have not been particularly helpful at the present state of development unless the coating is quite thick, and thick coatings are difficult to hold in place. In addition, thick coatings are not appropriate for some designs which depend on small louver openings to admit air to sweep the surface and cool the liner.

Still another approach which has improved liner life has been to increase the wall thickness of the combustion chamber. Here again, the relation between strength and performance is evident, but added thickness results in additional weight, and in airplanes the payload is all-important. Therefore, increased metal thicknesses are not looked upon with favor.

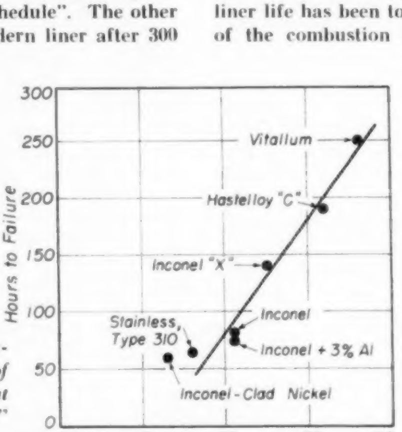


Fig. 2 — Straight-Line Relationship Between Tensile Strength of Material of Construction at 1800° F. and Life of Design "C" Liners in Cyclic Endurance Test (an Accelerated Life Test)

Most progress toward more durable liners has not been through new alloys, heat treatments, or special processing, but rather through a re-design to give proper louver relation to airflow so as to reduce thermal gradients

and pressure unbalance. Furthermore, with good design, the luxury of highly strategic materials (which are usually costly and in very short supply) is avoided.

Jet Engine Diaphragm Partitions are the next part met by the flow of hot gas coming from the combustion chamber. These partitions are stationary vanes in the hot gas stream and direct it into the turbine buckets in the designed manner and direction. Their normal maximum operating temperature is 1650° F. Materials are at present adequate. If, however, the combustion system is not functioning as it should, the blowtorch effect produced in the combustion chamber reaches the partitions and overheats them. On the other hand, if the water-alcohol injection (a conventional procedure for improving the take-off thrust of jet engines) is not functioning properly, the diaphragm can be subjected to a quenching medium.

Such malfunctioning of the combustion system causes high thermal gradients and accompanying high stresses in diaphragm partitions, and if distortion does not occur, the stresses relieve themselves by localized cracking. It can therefore be said that good performance of a diaphragm partition under all possible conditions is a function of high-temperature strength and ductility. Weak and very ductile materials buckle; although they do not crack, they lose their aerodynamic efficiency. On the other hand, a strong material, possibly with less ductility, tends to crack rather than distort. A good combination of properties for the diaphragm is possessed by cast Vitallium, an alloy of chromium, molybdenum and cobalt.

In the laboratory, diaphragm partitions can best be evaluated by a thermal shock test — alternately heating in a gas flame to 1700° F. and water quenching to a fixed cycle (4 min. and 50 sec. to 1700° F.; water quench 10 sec.). A cracked partition after such thermal shock testing looks very much like a twin which encountered faulty operation conditions in an engine.

Several cast materials made into diaphragm partitions of design "B" have been so evaluated in the laboratory, with results as shown at the top of this column. Cast Vitallium with 0.20 to 0.35% carbon is shown to be the best. Note that cast 25-12 did not crack but warped and distorted badly.

Engine tests have been run wherein the diaphragm contained partitions made of cast Type 309 stainless, Type 310 stainless, and Vitallium as well as fabricated partitions from Type 310 sheet, and have shown relatively outstanding performance for the cast Vitallium.

Laboratory Tests on Cast Partitions

Material	Cycles to Crack
Vitallium	
0.10 to 0.15% carbon	45
0.20 to 0.35% carbon	49
0.30 to 0.45% carbon	41
Alloy 6059 (0.27% C)	19
Hastelloy "C"	13
25-12 Cr-Ni	30 (warped)

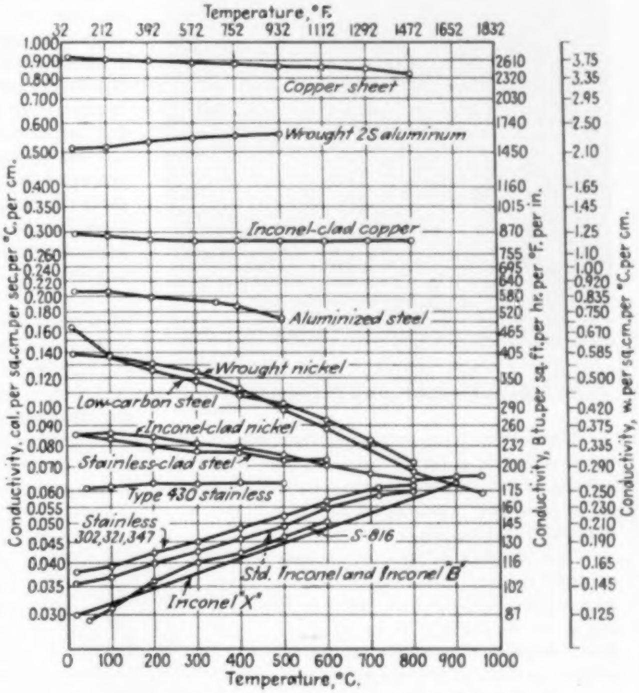


Fig. 3 — Thermal Conductivity of Sheet Metal at Various Temperatures. Whereas the group from Inconel "X" to wrought nickel has substantial differences at room temperature, it has about the same conductivity at 1500 to 1700° F. (P. A. Haythorne, The Iron Age, Sept. 23, 1948)

Fig. 4 — Section of Turbo-Supercharger Nozzle Box Showing Intercrystalline Cracking in Type 316 Stainless Sheet Welded to Cast Diaphragm (Upper Left)

Turbo-Supercharger Nozzle Box

The turbo-supercharger operates on the exhaust gas of a reciprocating engine and consists of a gas turbine for driving a compressor to increase the pressure of air delivered to the engine.

The nozzle box, which receives the hot exhaust gases, is made of formed and welded sheet metal and has a cast diaphragm as an integral part. Stresses within this assembly, which operates at temperatures between 1200 and 1650° F., vary with the installation in the airplane. If there is misalignment with connecting lines from the engine manifold, the nozzle box may be subjected to high alternating loads.

The sheet metal portion was made of Type 316 stainless for many years and operated successfully. Selection of this material was based upon its good high-temperature strength — better than that of other common stainless alloys. However, since the nozzle box operates in a sensitizing temperature range for austenitic stainless, this material became susceptible to intergranular corrosion, which, in some instances, caused it to fail. The exact corroding medium is not known, but it could well have been the products of combustion of high test aviation gasoline — namely, lead oxide or lead bromide and water. We changed to Type 347 stainless, and little difficulty has since been encountered with nozzle boxes. A photograph of a portion of one, shown in Fig. 4, shows intergranular cracking which led to the change from Type 316 stainless to Type 347 of heavier section.

Turbo-Supercharger Nozzle Diaphragms are subjected to the same general conditions of temperature and stress as the rest of the nozzle box; however, the partitions are subject to somewhat more severe stresses than some other parts of this assembly, because of the variable metal sections and because they are directly in the path of the hot gases, and generally of such dimensions that they must be of solid section and cannot readily be cooled.

Some early diaphragms were fabricated, but the thermal stresses normally present caused considerable trouble. The diaphragm that has given almost flawless service is a 25-20 chromium-nickel sand casting.

Fig. 5 — Unsound Center in Forged Turbine Wheel of High Alloy, Cut Along Axis After Indications Were Shown by Supersonic Inspection

Comparatively recently, a cast diaphragm failed from development of hard, brittle sigma phase in the microstructure, together with higher-than-normal stresses. The carbon content of this diaphragm was very low (0.05%) which contributed to the formation of ferrite, and, in conjunction with the operating temperature, undoubtedly resulted in the appearance of the embrittling sigma phase.

The regular carbon level is approximately 0.15% (0.12 to 0.18%) and the presence of sigma has not been observed in such higher carbon diaphragms withdrawn from service.

Turbo-Supercharger and Jet Engine Turbine Wheels have not failed due to temperature effects. Wheel failures have been associated with forging cracks, or poor metallurgical conditions at the wheel center — particularly in large sizes. By this is meant that

forgings may contain internal flaws or have low ductility (Fig. 5). Such defects are difficult to locate without destroying the wheel, although X-ray and supersonic methods have been extremely helpful in preventing failure in test or in engine operation.*

This problem of manufacturing difficulties has been largely overcome by several approaches — chiefly through the production of sound ingots by a continuous melting process, by improved forging practices, and by the use of a composite wheel, where the high-temperature austenitic alloy (Timken's 16-25-6 Cr-Ni-Mo alloy) is used at the rim only, and the hub and disk section is a heat treatable alloy steel (A.I.S.I. 4340), arc welded together. Because of the extremely successful operation of this composite wheel, the trend is to increase the diameter of the alloy steel center and reduce rim width, thus making a less expensive assembly both from a dollar-and-cents and strategic alloy standpoint.

The temperature of the turbine wheel is a fairly uniform gradient from approximately 1200° F. at the rim to 400 at the center. The limiting factor here lies in the creep strength, since clearance of the stationary shroud and the buckets is held as close as possible for best turbine efficiency; rubbing between shroud and buckets is obviously undesirable. Short-time room-temperature yield strength is also important, to pass high-speed testing for general proof of each assembly. Some alloys, strong in creep and rupture at design temperature, are not usable because of poor center ductility and low yield at room or moderately elevated temperatures.

Turbo-Supercharger and Jet Engine Turbine Buckets operate between 1200 and 1500° F., and fail either by stress-rupture or fatigue. Whether or not the failure is due to one or the other is often controversial, but the assigned cause of failures of small buckets for turbo-superchargers has usually been stress-rupture. The turbo bucket has always been a very short bucket and includes a shroud as part of the design. On the other hand, the jet engine bucket, with few exceptions, has been shroudless, and failures have been generally of the fatigue type. (Engine buckets with shrouds have had stress-rupture failures, many of which may have been associated with thermal shock.)

Shroudless gas turbine buckets have failed in a high percentage of the cases in the same location, which can be associated with a Chladni vibration sand pattern at extremely high frequencies. The points of failure have been indicated to be an area of probable high stress. These patterns, however, have all been made at room temperature and the exact effect of operating temperature on these patterns is unknown; they are undoubtedly changed in some manner, since the modulus of elasticity of the alloy lowers with an increase in temperature.

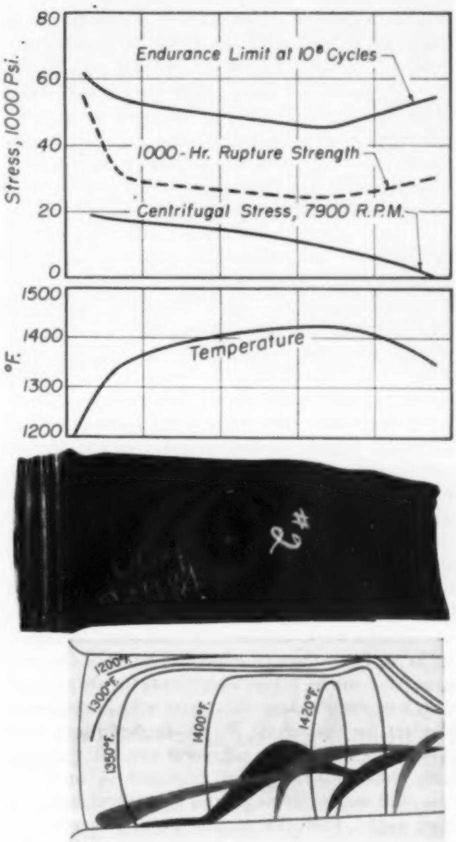


Fig. 6 — (Top) Average Stress and Temperature of Gas Turbine Bucket of Obsolete Design "B"; Also Endurance Limit at 10^8 Cycles and 1000-Hr. Rupture Strength at Respective Temperatures of Alloy S-816. In the center is a photograph of a bucket with a failure at exit edge, $\frac{3}{4}$ in. from the tip. At bottom is the temperature distribution on the face of a bucket and Chladni patterns, dark for 5850 cycles per sec. excitation, and light for 8000 cycles

Some interesting information was developed during a metallurgical investigation of Design "B" bucket, in which failures have been of a

*Editor's Footnote — See, for example, the article "Ultrasonic Testing of Gas Turbine Disks" in *Metal Progress*, April 1950, p. 468.

fatigue nature with but few exceptions. It is made from forged S-816 alloy, a complicated composition of C, Cr, Ni, Co, W, Cb, and Mo.

Figure 6 gives the average centrifugal stress along the blade, according to the designer's calculations. In addition, it shows the operating temperature, the available 1000-hr. stress-rupture strength, and the endurance limit for 10^8 cycles at the working temperatures.

(The temperatures from root to tip of the bucket were determined by operating a bucket of Inconel "X" — an age hardenable alloy — for a known period of time; then, by correlating the resulting hardness with age hardening curves for this material as affected by time and temperature, the distribution of temperature during operating was determined. Confirming evidence has been established by placing hardened high speed steel pins in drilled holes in the bucket and by determining the change in hardness after several hours of operation.) It is to be noted that there is considerable margin between the strength available (either rupture strength or endurance) and the average centrifugal stress. Even so, the majority of failures in this design have been ¾ in. below the tip on the exit edge.

Cracks have also been found approximately ½ in. in from the exit edge and parallel thereto, near the pitch line; these were generally of incipient nature and of a type which appeared to start on the inside of the bucket blade and progress to the back. Several cracks, particularly those near the pitch line and ½ in. from edge, did not progress all the way through to the back side. Failures of this type occurred not only in S-816 but also in cast Vitallium buckets of the same design under test.

Fig. 7 — Approximate Relationship Between Life of Design "C" Buckets and Endurance of Alloy at Average Operating Temperature

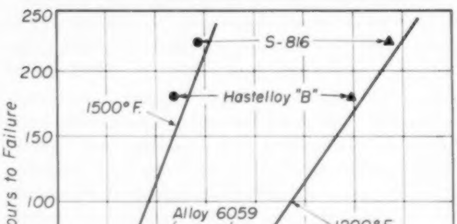


Figure 6 also shows, at the bottom, the temperature distribution of the Design "B" bucket. Superimposed on this are sand pattern lines which are the result of two exciting frequencies. The light and dark shaded areas are those produced by excitation of 8000 and 5850 cycles per sec. respectively. There is a possible correlation between the 8000-cycle pattern and the location of the failures ½ in. in from the edge and parallel thereto. It is to be noted, however, that there has been no systematic distribution of cracked buckets within a given wheel.

Design "C" buckets, made of a number of different alloys, were run in engine tests. A relation appears to exist between the fatigue strength at 1200 and at 1500° F. and the hours-to-failure in the test cell (see Fig. 7). Such a relationship cannot be drawn for Design "B".

The small turbo-supercharger buckets have given a fairly good relation between laboratory stress-rupture strength and hours-to-failure in operation; as the stress-rupture strength increases, the performance life also increases.

The metallographic analysis to determine

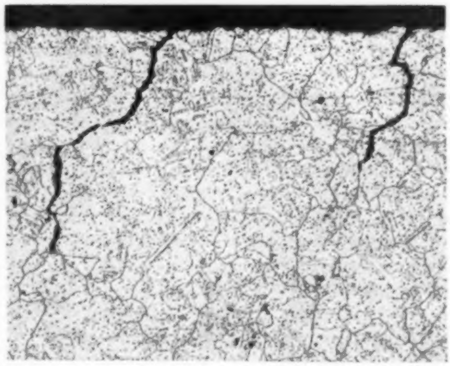


Fig. 8 — Intergranular Cracks From Inlet Edge of S-816 Bucket Caused by Thermal Shock. 100×

whether or not the failures were of a stress-rupture or fatigue type has been based upon whether or not the fracture was intergranular or transgranular. The assumption that intergranular fracture is indicative of a stress-rupture failure is believed to be sound for S-816 and also Vitallium — but with some reservations, for the normal temperatures and times of operation; longer time and higher temperatures could well cause both the stress-rupture failure and fatigue failure to be intergranular. Whether the fracture is intergranular or transgranular is dependent upon the strain rate and temperature.

The extremely high frequency Chladni patterns that correlate with the zone of failure, such as shown in Fig. 6, would indicate that it does not take very long to cause failure under resonant conditions if the stresses are above the endurance limit. The time interval could be a matter of minutes or only three or four hours for 10^8 cycles.*

Since the time interval to cause fatigue failure is small, a material with a high fatigue strength and with a relatively low stress-rupture strength could operate well in a design with a fairly high vibrating stress. Hastelloy "B" is an example of such an alloy.

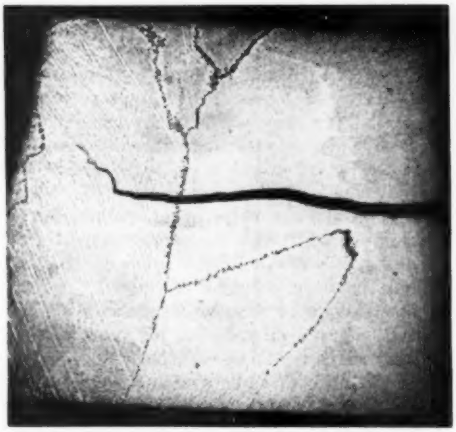


Fig. 9 — Transgranular Failure in Cast Vitallium Bucket, Probably Caused by Fatigue. 5×

Metallographic specimens would usually be prepared so as to include the point of crack nucleation, although the exact point where failure started is sometimes hard to establish. It may start by thermal shock or by stress-rupture; then, since all designs are subject to alternating loads, the crack may progress by fatigue; finally the transgranular portion of a crack may again become intergranular (stress-rupture) from increased load on reduced cross section.

As an example, Fig. 8 and 9 are respectively a micrograph at 100 diameters and a macrograph at 5 diameters of S-816 and cast Vitallium buckets. Figure 8 shows intergranular cracks in S-816 caused by thermal shock, and Fig. 9 is a transgranular crack in cast Vitallium, probably caused by fatigue.

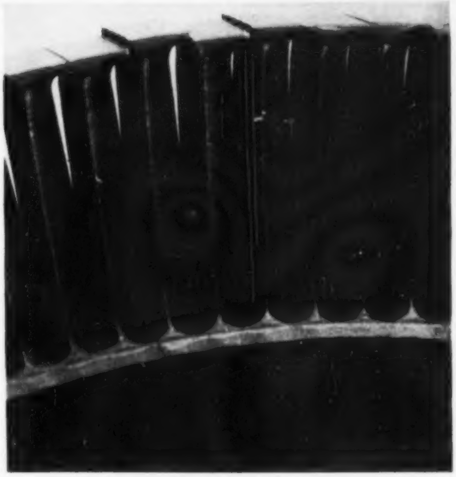


Fig. 10 — Design "B" Buckets of Cast Alloy 190 Showing Effect of Creep at Unduly High Temperature. Note extension of buckets whose shroud was originally in a smooth circle

Figure 10 is included to show the effect of creep in turbo-supercharger buckets after many hours of test operation under much higher than ordinary operating temperatures.

Manufacturing Precautions — Design "B" buckets which failed by fatigue have not shown a different distribution of grain size nor hardness when compared to buckets which have run satisfactorily for a similar period of time.

Process control in the melting, rolling, and subsequent forging and heat treatment of forged gas turbine buckets is extremely important. One particular hazard in forging and heat treatment is the tendency to grow very large grains — "elephant grains", as they are called. Conditions for producing these very large grains are a critical amount of deformation during cold finishing and a subsequent high solution treating temperature. The large grains are not found throughout a bucket section, but only in those regions which have had a certain amount of cold work. Variable grain size is thought to be unfavorable to best bucket performance — that is, resistance to thermal shock and vibrating loads. Figure 11 shows "elephant grains" in a bucket of S-816 alloy. This phenomenon has also been observed in other high-temperature alloys.

Many of the high-temperature turbine bucket alloys tend to have low ductility between 1200 and 1500° F. (as measured in short-time tensile tests). This is right in the operating temperature range. It is also just below the bottom of the normal forging range, and so the hammerman cannot forge safely at too low a temperature.

*This accepted endurance limit would better be defined as "fatigue strength", since the S-N curves for alloys so far tested do not appear to flatten out completely at elevated temperatures (1200 to 1500° F.) to show a true endurance limit.

Table I — Desirable Properties for Critical Gas Turbine Parts

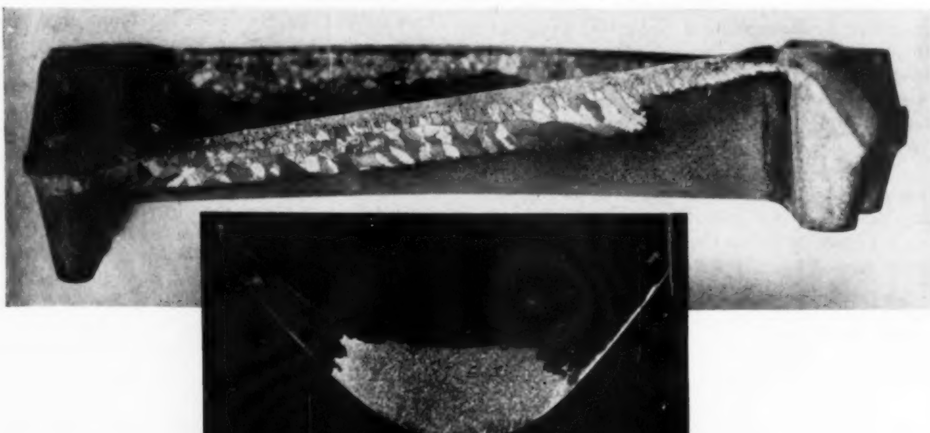
Physical Characteristics	Manufacturing Characteristics
Jet Engine Combustion Liner, 900 to 1800° F.	
Oxidation and corrosion resistance	Sheet
Thermal shock resistance	Formable
Strength	Weldable
Ductility	
High thermal conductivity	
Low thermal expansion	
Jet Engine Diaphragm Partition, 900 to 1650° F.	
Oxidation and corrosion resistance	Castable
Thermal shock resistance	Weldable
Jet Engine and Turbo-Supercharger Wheel, 400 to 1200° F.	
Good creep strength	Forgeable
Strength at moderate temperatures	Machinable
Ductility	Weldable
Jet Engine and Turbo-Supercharger Bucket, 1200 to 1500° F.	
Creep strength	Formable
Good stress-rupture characteristics	Machinable
High fatigue strength	Weldable
Resistance to thermal shock	
Ductility	
Oxidation and corrosion resistance	
Jet Engine Tail Cone, 900 to 1400° F.	
Resistance to thermal shock	Sheet
High fatigue strength	Formable
Oxidation and corrosion resistance	Weldable
Turbo-Supercharger Nozzle Box, 1200 to 1650° F.	
Oxidation and corrosion resistance	Sheet
High fatigue strength	Formable
	Weldable
Turbo-Supercharger Diaphragm, 1200 to 1650° F.	
Oxidation and corrosion resistance	Castable
Resistance to thermal shock	Weldable

Cracks from such a cause are found particularly on small buckets forged to size, or large buckets with thin edges forged to size (a standard practice). Not only can this low ductility range cause trouble in the forge shop but it can also be harmful to engine operation. Any misalignment in assembly or design configuration that requires some plastic flow in the initial period of running to reduce a stress concentration requires ductility. Without ductility, or with low ductility, stresses could become high enough to cause rupture. Similarly, any thermal shock conditions that might be encountered during running would be more harmful to a part with low ductility than one with high.

Jet Engine Tail Cone structure is made of welded stainless sheet, Type 347. It acts to retain the exhaust gases and therefore is subject to some unbalanced pressures. Temperature gradients are encountered with improper engine operations, but these gradients are generally not very sharp and thus the thermal stresses encountered are not as severe as in some other parts of the engine. The tail cone ranges from 900 to 1400° F. in extreme cases of maldistribution of temperature. Stronger materials improve life, but the real solution to this problem has been brought about by improved design.

A summary of the general physical characteristics required of materials for application to the hot parts of turbo-superchargers and jet engines is given in Table I. Since, however, the shop problems of manufacture and assembly are of such great importance, the right-hand column is included. Based upon the present concepts of manufacturing in America, these items are of equal significance.

Fig. 11 — "Elephant Grains" in S-816 Bucket. Note large grains at edges and fine grains in center of cross section



By Leo Schapiro
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Modern Trends in Airframe Materials

THE WORD "trends" in the title implies a comparison; the words "modern trends" imply a comparison with some long bygone past. The airframe industry is not yet old enough to have a long bygone past. If the comparison were made with only 25 years ago, the story of progress would glow gloriously. I shall strike a more modest pose and make a comparison with only ten years ago.

We should begin by first defining an airframe. For the purposes of this discussion an airframe will consist of a fuselage, wings, tail, nacelles and landing gear. An airframe is constructed to fulfill three simple requirements. First, and certainly foremost, it shall be capable of getting off the ground and into the air. (This in itself is not a simple matter, for to fulfill this requirement the airframe must not only support its own weight but also the weight of at least one engine to move it, at least one pilot to operate the engine and guide the airframe, and certainly some fuel to give the engine life.) Second, the airframe shall be capable of supporting one or more engines of a size and power rating that shall give the airframe some usable rate of speed and shall be capable of carrying the weight of a reasonable quantity of fuel that shall carry the airframe to some reasonable distance without refueling. Third, the airframe shall be capable of carrying the additional weight of some usable payload.

These simple requirements add up to a simple choice of construction materials. The strongest materials of the lowest weight are all one needs to construct an airframe. Where greater strength is obtainable in the material without an increase in its weight, payload is thereby increased, or speed is increased if the power plant is available to produce the increased speed, or nonstop distance is increased. The story of progress is a tale of application of stronger or lighter materials as designers reach for greater payload, greater speed, greater distances between refuelings, or combinations thereof.

How did the transport airframe of ten years ago fulfill these three requirements? That airframe carried three times its own weight at a speed of approximately three miles per minute for a nonstop distance of approximately 600 miles. To achieve that speed, the weight of engines, instruments and accessories equaled the weight of the airframe. To fly 600 miles with a useful payload, the weight of fuel and payload together equaled the weight of the airframe. The airframe was constructed of the strongest yet lightest weight material then available — the aluminum alloy 24S with a tensile strength of approximately 60,000 psi.

In those applications where structural considerations dictated the use of steel with its higher elastic modulus, this three-times-heavier-than-aluminum material was used at a strength of 180,000 psi. to pay its way without a sacrifice of weight for equal load-carrying capacity.

That was the airframe of ten years ago.

The desire for greater speed and longer nonstop flights arose some time ago and was realized by airframes constructed of the materials of ten years ago. In fact, a speed of four miles per minute was achieved, together with a nonstop distance of 1800 miles. The greater air loads to which this faster airframe was subjected would have reduced the useful load-carrying capacity of this airframe had not improvements in aerodynamic smoothness kept apace. This four-mile-a-minute airframe carried engines, instruments and accessories slightly heavier than the airframe weight, as well as fuel for an 1800-mile flight plus payload equal to 1.6 times the airframe weight — a total of approximately 3.7 times the airframe's weight.

We have much faster aircraft today. The

airframe of today travels at five to six miles per minute for nonstop distances of 1800 miles or more. It supports engines, instruments and accessories equal to 1.2 times the weight of the airframe. It carries fuel and payload together equal to 1.7 times the weight of the airframe. Thus, it carries a total load equal to nearly four times the weight of the airframe and at a speed almost double the speed of ten years ago when the airframe carried a load only three times its own weight. In this progress the advances in aerodynamic smoothness have been aided by using a stronger material than the 24S aluminum of ten years ago — namely, the 75S aluminum alloy with tensile strength of 70,000 psi.

The aluminum industry's development of this stronger material sometimes looked like a "gift horse to Troy" to the airframe industry. And like the legend of yore, a look into the mouth of this horse revealed difficult problems to be reckoned with before the gift became fully assimilated. The new, stronger 75S alloy was not as easy to form as the lower-strength older material. The new 75S alloy was not as easy to join together. The new 75S alloy was not as easy to heat treat. The new 75S alloy was not as easily designed into a part. These problems the industry gladly undertook to solve to gain the prizes of greater payload, greater nonstop distances and greater speed which this 16% stronger but no heavier material made possible. (Please remember that this 16% gain was for static loads, but not for fatigue loads.)

The steel landing gear of this airframe is not yet as "efficient" as the 70,000-psi. aluminum components. To be as "efficient", the three-times-heavier-than-aluminum steel would need to be used at a 210,000-psi. strength level — possible, it is true, with the conventional chromium-molybdenum S.A.E. 4340 steel, but with misgivings in the minds of many designers. Its lowered ductility and impact resistance when heat treated to strengths of 210,000 to 220,000 psi. are, in the view of many airframe designers, too far from the time-tested and flight-tested ductility and impact resistance of 4340 at strengths of 180,000 to 200,000 psi. Thus, a requirement was born for a steel at over 210,000-psi. strength, simultaneously with ductility and impact resistance not less than the ductility and impact resistance of S.A.E. 4340 when the latter is heat treated to a 180,000-psi. strength level.

This requirement has only recently been presented, and the steel industry should be complimented on the speed with which it was fulfilled. Three companies now offer a 230,000-psi. steel whose ductility and impact resistance are not less than those of the time-tested S.A.E. 4340 at an 180,000-psi. strength level. A look at their properties should prove to be of interest.

Let us first look at their representative chemical analyses (Table I). It is apparent that they do not readily fit into the S.A.E. numerical classification system. While the differences in alloy content may appear striking, the low carbon content is especially interesting. It is not accidental, but is a deliberate effort to improve weldability. It is interesting to note that the lowered carbon content has not resulted in lowered hardenability. End-quench hardenability tests, Fig. 1, indicate that any of them will harden to the center of a 4-in. round, which is the largest shape an airplane designer may require. The lower as-quenched hardness results from the lower carbon content; this difference disappears after the usual tempering operation which brings them to the common strength level of 230,000 to 245,000 psi.

Ductility values are presented in Table I to illustrate the comparison with S.A.E. 4340 steel at both 180,000 and 230,000 psi. strength. Its ductility at the high-strength level may not appear to be too markedly lower than at lower strength (after higher tempering) but this effect, coupled with the lowered impact resistance, was

Leo Schapiro

This is the first of the papers read at a series of notable meetings in Oakland, Calif., during the Western Metal Congress and Exposition last month. Leo Schapiro, the author, graduated from Missouri School of Mines in 1924 (Ph.D. from Wisconsin in 1927) and worked for Carnegie-Illinois Steel Corp. for 16 years. In 1944 he joined Douglas's engineering staff, and after several promotions reached his present position of chief metallurgist of the Santa Monica Division. It may be more than an accident that the candid camera shot from which the above engraving was made showed a desk clear except for two magazines: *Journal of the Aeronautical Sciences* and *Metal Progress* — a fine combination of theory and practice, say we.

Table I — New Steels With High Strength, Ductility and Toughness

	Hy-Tuf (a)	B-514 (b)	Cr-Ni-Mo-V Type 2 (c)	S.A.E. 4340 (Datum)	
Analysis					
Carbon	0.25	0.25	0.30	0.40	
Manganese	1.35	0.80	0.90	0.65	
Silicon	1.50	0.60		0.30	
Copper		0.70			
Chromium		0.70	0.75	0.80	
Nickel	2.00	2.30	1.85	1.80	
Molybdenum	0.40	0.55	0.45	0.25	
Vanadium			0.10		
Properties					
Ultimate strength	235,500	228,700	247,500	180,000	236,500
Yield strength (d)	196,700	184,100	222,000	174,000	212,000
Elongation in 1 in.	23.5%	14.0%		23.4%	
in 2 in.	14.0		12.0	14.0	10.0
Reduction of area	49.2	54.8	47.8	45.0	35.0

(a) Made by Crucible Steel Co. (b) Made by U. S. Steel Co. (c) Made by Republic Steel Corp. (d) Psi. for 0.2% offset.

unnotched and notched specimens. These data illustrate that notch effects are no greater for the new steels than for the old under alternating load.

While the foregoing details regarding the high-strength high-tough steels may seem to praise them rather highly, it is important to remember that the useful high toughness of these steels is only present at the high-strength level. At lower strength, the new steels are not different from S.A.E. 4340 or other constructional alloy steels.

a mental hurdle to overcome, if not, indeed, a real one.

Impact Resistance

Steel	Temp.	Charpy	Tensile
4340 (a)	50° F.	38	
4340 (b)	50° F.	15	72
Hy-Tuf	50° F.	35	66
	0° F.	28	65
	−100° F.	15	64
B-514	50° F.	29	
	0° F.	28	
	−100° F.	26	

(a) Tempered to 180,000-psi. tensile strength.
(b) Tempered to 235,000-psi. tensile strength.

Fatigue resistance of these steels is yet to be mentioned. Axial-load, tension-tension fatigue tests with a ratio of minimum to maximum load of +0.25 are presented in Fig. 2, for both

One complication faces the airframe industry in the use of such high-strength steel — namely, one of specification interpretation. It will, no doubt, be resolved readily. This concerns the tempering temperature. To achieve the 235,000-psi. strength level, Hy-Tuf steel is oil quenched from 1600° and tempered at 550° F. This tempering temperature is within the blue-brittle range for S.A.E. 4340 or other previously used constructional steels, and is therefore not permitted by government specifications governing heat treatment. This temperature, however, is *not* within the blue-brittle range for Hy-Tuf

Fig. 1 — Jominy End-Quench Tests Indicate That New Steels Have High Hardenability (Depth of Hardening). Level of hardness corresponds to respective carbon contents

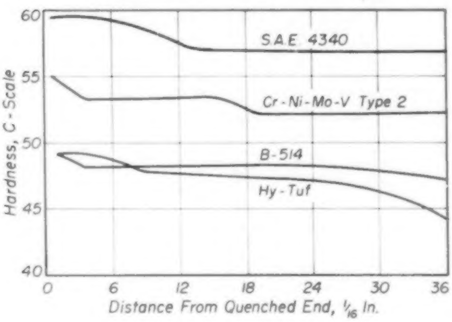
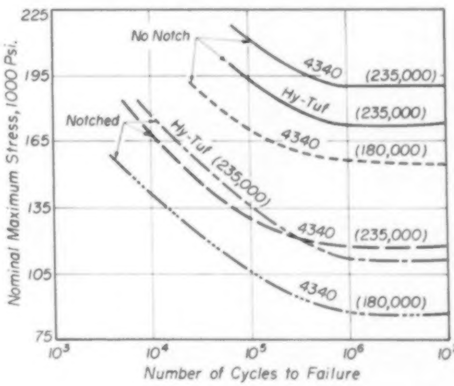


Fig. 2 — Axial Tension Fatigue Life (Minimum Stress 20% of Maximum) for 4340 and Hy-Tuf, Both Notched and Unnotched Specimens at Indicated Strength Levels



steel and therefore results in good ductility and good impact resistance. No doubt the official specification will some day recognize the different blue-brittle range of this unique chemical analysis and it will be re-worded.

Tomorrow's Needs

Having discussed the developments which are in today's airframe, let us try to look into the airframe of tomorrow. Speeds in excess of six miles per minute may be a reality for transport airframes sooner than one dares to predict. Advances in aerodynamics may enable the airframe to sustain these greater loads without using a stronger-yet-not-heavier structural material. The first phase of this development may occur in that manner, but the second phase will likely require the use of a stronger material.

To retain supremacy as the primary airframe structural material, aluminum has already been produced in an alloy 8 to 10% stronger for static loads (but not for fatigue loads) than the present 75S alloy. While the new alloy is not yet commercially available, and since the airframe industry is not yet ready to use it, the aluminum industry is studying this new alloy to determine what new production problems must be faced in forming, joining and heat treating.

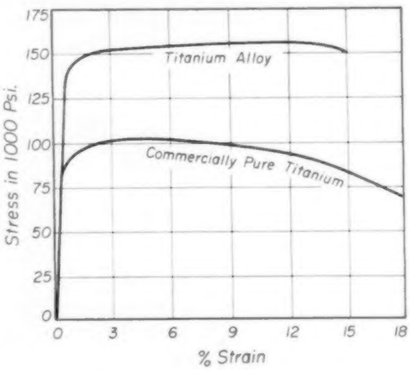
However, we must ask ourselves whether a 10% increase in strength without an increase in weight will meet the future requirements. As we look back over the past ten years, we are reminded that it took a 16% stronger material to help us advance from three miles per minute to more than five miles per minute. Will a prospective 10% increase in strength serve for the next advance?

One important new consideration is now present. As speeds exceed six miles per minute, aerodynamic skin friction will heat the surface of the airframe somewhat above ground temperature. Depending on actual speed, the skin may reach 300° F., and at such a temperature the strength of even the high-strength aluminum alloys is not particularly useful. Our next structural material may need to be one that is not only stronger than 75S on a strength-weight basis, but also one that has little loss of strength at aerodynamic-friction temperatures.

Because of this possible uncertainty, we now stare wide-eyed at the much discussed "wonder metal", titanium. With a density twice that of 75S, may it give us 20% more strength? A strength of 170,000 psi. would be required.

The "commercially pure" metal is short of this goal by almost 100,000 psi., and, at this low strength, it is not uniquely useful to the airframe industry as a structural material. It is finding some use in elevated temperature regions not exceeding 800° F. as a substitute for annealed stainless steel; at equal strength it saves one third the weight. But the airframe industry will feel the full impact of the new metal titanium if and when it becomes a structural material at 170,000 psi. or greater strength. This goal may actually not be too far away, since several alloys are already being intently studied, varying in strength from 140,000 to 180,000 psi. The needs of the airframe industry require that a high-strength titanium alloy be commercially developed.

Fig. 3 — Tensile Stress-Strain Curves for "Commercially Pure" Titanium and One of the Stronger Alloys



It should not be inferred that this development is awaited with wide-open arms as one would welcome the return of a much-missed friend. The new alloy may give the airframe industry even greater problems than did the aluminum alloy 75S. The forming, joining and heat treating of "commercially pure" titanium has been fraught with difficulties. A strong titanium alloy may offer even greater difficulties. A look at two stress-strain curves will illustrate this. In Fig. 3 is a stress-strain curve for a "commercially pure" titanium and one for a 150,000-psi. alloy. The low ductility and relative ratio of yield to ultimate strength of the "commercially pure" titanium are respectively lowered and raised still more in the alloy. Both of these indicate difficulties in forming. But the airframe industry is slowly but surely altering many of its operations from room temperature ("cold work") to moderately elevated temperatures ("warm work"), and the revisions

necessary to handle new construction materials may not be really severe.

A second possibility may be a new magnesium alloy. At two thirds the weight of aluminum, magnesium at a strength in excess of 45,000 psi. can be a desirable construction material — especially since its loss in strength at aerodynamic-friction temperatures is not as great as is aluminum's. However, the airframe industry has slowly nibbled at the problems attending the forming of magnesium but has not yet digested this subject. A more "formable" magnesium alloy with the desired strength is therefore an interesting development. Some 7 to 9% of lithium seems to improve formability by creating a cubic phase in this otherwise hexagonal metal. However, the alloy is of low strength. Added alloying elements improve strength to the desired levels but also detract from formability.

Speeds in excess of six miles per minute present an additional problem besides skin-friction temperatures. Such speeds will probably be attained by the use of gas turbine power plants in place of reciprocating engines. To the airframe industry, mounting the power plant within the fuselage instead of outside the airframe is one possible configuration and this presents an additional problem. Insulated as the jet engine may be within the fuselage, radiant heat is sufficient to raise the temperature of at least some of the fuselage structure to approximately 600° F. Thus, again, the search is on for materials to "pay their way" on a strength-weight basis at this temperature. The high-strength titanium alloy — when developed — may fill this need adequately. In the interim, the garden varieties of 18-8 stainless steels have been used in their harder, cold rolled tempers to pay their way weightwise. This has been the only available material for the application and it has been totally inadequate.

Forming operations with these hard tempers have been more than a headache — they have been dangerously close to being a total loss. Breakage in forming has been inordinately high. Other difficulties arise from the fact that the cold worked tempers have guaranteed minimum strengths, yet the maximum strengths have been too varied to permit a die to serve adequately from one shipment of material to the second shipment.*

*Editor's Footnote — At the same meeting in Oakland a paper was read describing equipment for grading formability of austenitic 18-8 by measuring its magnetic susceptibility — a measure of the ferrite in the cold worked microstructure.

There is now hope for a solution to this problem. The precipitation hardening stainless steels offer the desired high strength and oxidation resistance as well as the particular advantage of being formable in a condition softer than the final strength. Three such steels are now commercially available; their strength and ductility properties are particularly interesting. Elongation in a 2-in. gage length is fairly good; while this figure is hardly an adequate guide to formability, it is sufficiently indicative to emphasize the more formable character of the precipitation hardenable steels in contrast with cold worked stainless. (Improving the formability of 18-8 with subzero forming is a development that has not yet reached commercial operation.) Of the three precipitation hardenable steels, the 17-7PH is finding the greatest application, in view of the high strength to which it can be treated, coupled with its ready formability before hardening.

Conclusion

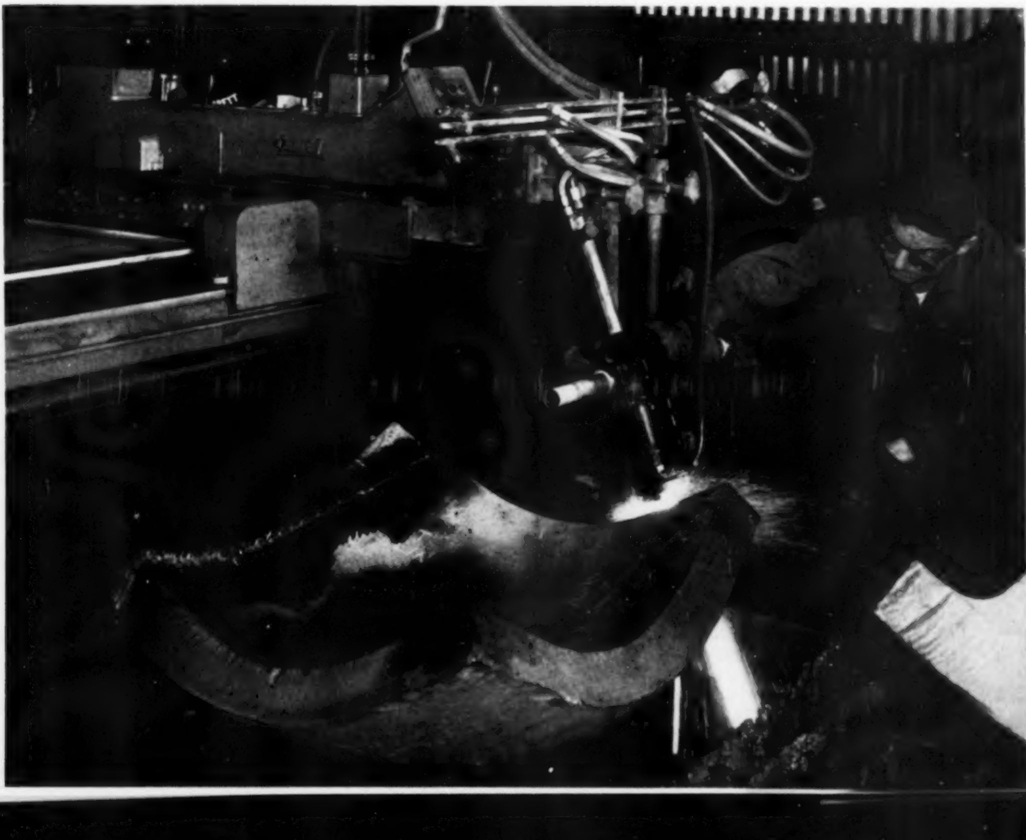
These comments have only covered major trends in airframe materials and have not included specific airframe parts for which other metals than those mentioned are being used or being developed. The time hardly seems adequate to cover these details.

Spherical Pressure Tank

Welded From Stainless Plate

WELD FABRICATION and the use of an "exploded" cube design provided the combination needed to obtain high strength at relatively low weight in this spherical tank. The storage vessel — made by Research Welding and Engineering, South Gate, Calif., for use by the U. S. Air Force in rocket-propelled aircraft experiments — is designed to hold 200 gal. of liquid nitrogen at 5500 psi. at $-340°$ F. Weight of the 54-in. diameter sphere is 7500 lb.; alternate proposed designs would have ranged in weight up to 15,000 lb. Its $3\frac{11}{16}$-in. thick plates of Type 347 stainless were joined by multiple-pass arc welding using a lime-coated 18-8 type rod. Following the welding operation the sphere was annealed by heating it for $3\frac{1}{2}$ hr. at 1950° F. and then quenched with the use of internal and external high pressure water spray.

TRIMMING and beveling of the shaped plates was done simultaneously using the Linde powder cutting process. Use of the flame cutting machine saved an estimated 30 days' fabrication time. Slag and residue left by the trimming operation were removed by grinding after which the plates were pickled to safeguard against contamination.



BACKING strips held the parts in place until the root weld could be made. First weld passes were made with Heliarc welding; joints were filled by multiple-pass arc welding using a General Electric Type 1347 coated rod. Approximately one ton of weld rod was used to join the plates. Tank was made from six 38 x 38-in. plates which were heated to 1700° F. and press forged to 22.500-in. spherical radius.

GAMMA ray and a dye penetrant method called "Dy-Check" were used to test the welded joints. These inspections were made after the Heliarc welding and as the welds were built up.

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Metal Failures in Aircraft

THE failure of metal components in aircraft structures has been the subject of much research and many technical publications. For the most part these studies have dealt with the problem from the design and manufacturing standpoint. It is felt that this situation tends to distort the over-all picture in the eyes of many metallurgists. The relative importance that a metallurgist may give a tagged part, as received in the laboratory, may be quite different to that given it by a maintenance engineer in the field. This article endeavors to portray the problem from the maintenance viewpoint. The cases cited should in no way be taken as a statistical survey but only as representative samples which were encountered in the field.

Metals comprise a very large percentage of all highly stressed parts in an aircraft, regardless of whether or not the airframe is categorized as all metal or a composite structure. The study of metal failures in these structures is important because:

1. The safety factor is much lower in aircraft than with most other structures, due to weight saving being all-important. Sections are decreased and the stress intensity increased to the limit.

2. The failure of a relatively non-important part in an automobile or a stationary machine usually entails very little general damage and at worst a shut-down. An equivalent type of failure in an aircraft may lead to disastrous results.

3. An aircraft is more carefully engineered with a view to preventing metal failures than any other general type of structure. This is necessary, due to the consequences that may follow even a minor type of failure as mentioned in 2. Human life, valuable equipment, and a concern's reputation depend on the proper functioning of a multitude of parts to a much greater extent than we normally encounter in most machines. Consequently, if effort is expended in the direction of failure control, results are expected.

Investigation of Failures — A metallurgist involved in an investigation should bear in mind the background of the failure and endeavor to obtain as much unbiased information as possible that will assist him. He should realize that he is examining, for the most part, samples which are preselected with respect to the whole failure population. Many failures are not brought to his attention unless unusual circumstances arise such as a fatal accident. The place to obtain a true perspective is on the field where operational failures are first encountered. Chief concern of a maintenance engineer is serviceability. The term, serviceability, may be defined as "the percentage of the time that an aircraft is in an airworthy state over a given period". The effectiveness of any individual aircraft in service may therefore be measured by its serviceability and its flying intensity.

Realization of profitable operation from the maintenance standpoint requires an efficient organization and eternal vigilance. Metal failures are a contributing factor in lowering serviceability and in demanding this high degree of vigilance. Many minor and commonplace failures take their toll in

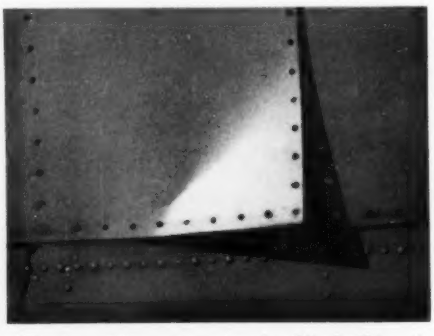

Fig. 1 — Rivets Securing the Metal Skin of an Elevator Failed During Abrupt Maneuvers

the grounding of aircraft in addition to those better publicized ones which have, perhaps, been involved in special investigations.

The channels through which information travels may contribute certain contradictory evidence to the metallurgist. To illustrate this point, take a hypothetical case of some broken part. A mechanic brings the failure to the attention of the maintenance engineer. Two questions arise in the engineer's mind; what caused the failure, and who is responsible. The cause may or may not be determined in the field. Some breakages, especially those in badly damaged structures, defy solution.

Keep in mind that the average maintenance engineer is not a trained metallurgist, nor has he the time or facilities to examine the part metallurgically. He tries to determine from the available facts if his maintenance was responsible, and if so, how he can avoid future trouble of similar kind. It is only natural that a defensive attitude be adopted regarding the work which he is supervising. This sometimes results in the suppression of information if it reflects poorly on maintenance.

An additional cause of lost statistics is the assumption by a maintenance engineer that the breakage was fair wear and tear, and hence no damage resulted. Therefore, the part is replaced and the subject is dismissed. It is easy to condemn the maintenance engineer's judgment of the failures he reports. However, he cannot debate for hours the merits of initiating a failure report and still keep up his other duties. His main objective is to get the aircraft back to duty and then worry about the paper work.

Next, assuming maintenance is not to blame, what about abuse by the aircrew? Has the pilot overstressed the part accidentally or deliberately? Information on this phase is often hard to piece together and occasionally demands extensive sleuthing. Let us categorize our failure as being sufficiently important to warrant reporting. A defect report of some type is drawn up and forwarded to higher authority in the organization. The original information gathered at the field plus comments en route eventually reach the manufacturer.

Field representatives of the manufacturer often short-circuit this route, of course, by direct reporting. The maintenance engineer may have questioned the design or indicated some defect in workmanship of the part. It is quite conceivable, on a failure where the responsibility is hard to assign, that considerable discussion may arise between designers, production staff and metallurgists, with the pilot and maintenance engineer being dragged over the coals in absentia. This discussion is good if it is constructive.

Fig. 2 — Seven Engine Mounts Failed at Weld Cluster Under Mounting Pad. Poor welding technique is responsible for weak zone alongside weld

It is not intended from our discussion to create an impression that every aircraft failure receives the attention or is as controversial as our hypothetical part. Complete cooperation is necessary, however, if confusion and contradiction are to be avoided. A reasonable solution can be arrived at only if all parties concerned give full and accurate reports on their phase of the problem. The man in the field does not know all the answers nor does the man in the design office or on the production floor.

Failure of Components

An airplane is far from being a "deacon's masterpiece", even up to the time of its first major overhaul. As an aircraft continues in service, a continual struggle is waged to hold defects and failures under control. The nature and frequency of metallic defects vary, of course, with different types of aircraft, their age, duties, maintenance and other factors. Excluding outright overstressing, the common failures such as might be due to fatigue, corrosion or wear will be composed of two general types. First, those accidental types of failure which we try to avoid, and secondly, those anticipated failures which are the result of deliberate design.

An aircraft is generally designed for some approximate service life. For example, a World War II bomber had an expected life of under 200 hr. whereas a commercial transport is expected to fly 20,000 to 30,000 hr. An aircraft designer, unlike his counterpart in other transportation fields, normally dimensions certain parts down as low as possible with the result that they have a corresponding shorter life. This necessitates that many parts be replaced periodically during service rather than have to carry the extra weight of longer lasting parts throughout the entire life of the aircraft.

The methods employed to estimate the safe life of certain aircraft components, such as main spars, is very empirical and is currently the subject of much research and discussion. This entire business of compromise between performance and life throws a heavy load on aircraft maintenance, whose standards must be high if operations are to be carried on successfully.

A cursory survey of publications (and the existence of many photographs depicting broken parts) will usually convey to the reader the idea that it is the highly stressed components such as propellers, crankshafts and gears which give most cause for concern. It is true that occasionally these parts do give trouble but probably not nearly to the same extent as in the earlier days of aviation. As a result of the great attention these parts have received from research, design and production personnel, they perform remarkably if given reasonable maintenance care. The same degree of effort could well be spent in improving some of the more commonplace components. A few specific areas where additional attention should be focused are:

Exhaust Systems — These are all too often a source of continual trouble. True, they do not as a rule cause damage or fire which may destroy an aircraft. Nevertheless, the man-hours spent in checking, patching, and changing such items as stacks, collector rings, support brackets and tailpipes is far too high. A well-designed exhaust system should be capable of taking an engine through to its complete overhaul without the excessive amount of maintenance that most of them now demand. Except for low powered engines, the use of mild steel has generally given way to other materials, although its low cost, good formability and weldability were excellent despite its short life. The authors are not qualified from personal experience to compare the performance of ceramic coated exhaust systems with others in current use. The vast majority of high output engines now employ an 18-8 type stainless steel or else Inconel. The use of Inconel from a maintenance point of view is most strongly recommended.

Excellent exhaust systems can be fabricated out of stainless steel, as countless technical papers have described. To accomplish this, tight control over materials, welding and heat treatment must be exercised. Many points such as the use of correct welding rod, properly stabilized base material, prevention of zinc pick-up from the forming dies, and avoidance of carbon pick-up due to flame adjustment or carbonaceous material in the rod coating must be watched. It has been the writers' experience that during wartime this degree of control is not achieved in many cases. Inconel on the other hand is relatively immune from these *difficulties* with the result that it outperforms stainless.

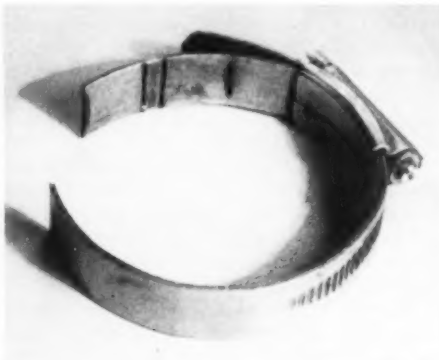

Fig. 3 — Fatigue Failure in Coupling on Coolant Line Stopped Engine Within a Few Seconds

Although the initial cost of Inconel is greater than stainless, and its value from a strategic point of view is a wartime drawback, it is the finest exhaust system material available. Inconel will invariably last throughout the complete overhaul time of an engine with little if any repairs. The reduced maintenance, increased reliability and longer life (usually 3 to 4 times that of stainless) make it a more economical material than stainless. In support of the wider use of Inconel, it has been the writers' experience on several airfields where Inconel and stainless exhaust systems were in use on the same type of aircraft that all Inconel components from crashed and time expired engines were carefully removed for spares to replace stainless parts as soon as convenient. This action on the part of maintenance personnel gives a better clue to actual performance than most tests.

General Sheet Metal Work — Practically all common aircraft sheet metal failures involve the presence of high internal stresses. The use of insufficient bend radii is frequently a source of trouble. Many components are left in a high state of internal stress after forming. The condition is often further aggravated by riveting or welding during assembly. This leads to possible failure by fatigue or stress-corrosion cracking. Although most failures of this type are readily spotted and are seldom disastrous, the man-hours consumed in repairing or replacing these components are not often appreciated.

Torquing of Bolts and Studs — The failures due to the improper tensioning of dynamically loaded bolts and studs are largely the responsibility of maintenance personnel. This is the classic example of a type of failure that is seldom, if ever, reported on for reasons previously mentioned. There are far too many bolts and studs broken needlessly in service that we never hear about. The development of a foolproof and simple device for ensuring proper bolt tension would be a great boon in maintenance.

Engine Mounts — Currently this item is receiving more attention but to date we have not given it, and particularly the welded mounts, sufficient study. It is obvious that the resistance to fatigue must be high for such a vital part as this. Many engine mounts are difficult for maintenance personnel to thoroughly check on daily and minor inspections. Cowlings must be removed and even then the engine with its accessories, controls and plumbing frequently presents a formidable obstacle for visual examination.

Welding — Probably no fabricating technique relies so heavily on the skill of the individual as welding. This fact is important in aircraft construction because so many different alloys are welded and for the most part they are all relatively thin sections. Welding is often at the bottom of difficulties encountered in engine mounts, exhaust systems and to a lesser extent in sheet metal work. The majority of failures in the field usually can be laid against the welder's technique rather than the design or materials used. Careful inspection of welds and continual supervision of the welders are essential.

Responsibility for Failures

A number of metal failures encountered in service are illustrated in the accompanying photographs. These failures are very briefly described. A limited number of them have been examined metallographically by the authors. No correlation should be drawn between the frequency of any particular type of failure and the number of illustrations shown. The photographs were selected to portray a typical cross section of the types of metal failures which a maintenance engineer must size up in order to decide what action is necessary.

The division of responsibility for metal failures is a very difficult problem as has been indicated previously. No definite line can be drawn due to the presence of so many variables. Different types of aircraft, different manufacturers and different kinds of operations all complicate the picture.

Responsibility for failures may be assigned to *(a)* design, *(b)* manufacture, *(c)* maintenance, *(d)* pilot abuse and unknown. Based on operations over a five-year period with about 500 aircraft ranging in type from small single-engined elementary trainers to four-engined bombers, we found that 50% of the failures could be attributed to design, 25% to manufacture, 15% to maintenance, 10% to pilot abuse and unknown. These percentages are general approximations and are not the result of a statistical survey.

To the designer falls the initial problem and his action, more than that of anyone else, contributes to the resultant product. The material specifications, the finishes demanded, the heat treatments specified, and the care taken in the design of all components on fillets, oil holes, splines, threads, fins, changes in sections and a multitude of other detail may make or break an otherwise excellent structure.

The most perfect design can easily be ruined by poor production methods and processes. Incorrect heat treatments, substitution of inferior materials, grinding cracks, scratches, tool marks, poor machining, careless handling and inspection, all contribute their share of potential grief.

The statement that "an aircraft is as good as its maintenance" contains a great deal of truth and has a direct bearing on the performance of metals in aircraft structure. Probably the most important phase of maintenance in this connection is the exercising of preventive maintenance and thereby preventing or catching potential failures before they have caused damage. Maintenance also plays an important part in overcoming corrosion problems. The maladjustment of components, carelessness in handling parts and tools are additional ways in which metal life is shortened. One of the most serious problems of all is that of maintaining the correct tension on all dynamically loaded bolts and studs. The total percentage of failures attributed to maintenance is markedly affected by wartime

conditions where skilled personnel are usually well diluted and working conditions and facilities are not comparable to scheduled airline standards.

Despite careful investigation, a small percentage of failures is due to unknown causes. Badly damaged structures account for most of this category. Pilot or operator abuse is another cause of failures which is often exceedingly difficult to allocate. The finest of machines may be needlessly overstressed, abused or generally pulled apart by careless or indifferent pilots.

So far the role of the metallurgist has not been defined. His main endeavor in the prevention of failures is diverted into the first two categories, namely design and production. In these two fields he can contribute a great deal if allowed proper scope and given adequate cooperation.

In the field of aircraft metal failures, the metallurgist has already made large contributions. Relatively speaking, he has made more than the aeronautical and mechanical engineer in this respect. Future progress will depend largely on the design and production engineers paying more attention to their own detail rather than adopting the somewhat lazy attitude they have in the past of demanding of the metallurgist some new material, alloy or treatment to pull them through.

As has been pointed out by J. O. Almen ("Fatigue of Metals as Influenced by Design and Internal Stresses", *Surface Stressing of Metals*, A.S.M., 1946, p. 33), the metallurgist is responsible for only 10% of all metal failures. This does not mean that the metallurgist can relax but he must convey some of his specialized knowledge to the designers and assist them in cleaning up their designs from a metallurgical aspect and controlling the production job.

Suggested Failure Control Methods

The statement has been made that our basic aircraft structural materials are no stronger now than they were in the days of World War I. It is true that certain aluminum and magnesium alloys have increased slightly in strength but, nevertheless, the general conclusion is still valid. Despite our increased knowledge of the metallic state, no super-alloy development appears imminent. Remarkable strides have been made in production methods, fabricating techniques, quality control and other fields which in turn have improved the reliability of metals in service to an extent which permits greater utilization of existing strength in design. Over this period from the 1914-18 era to the present time, as we all are aware, the performance and size of aircraft have increased tremendously. Aircraft improvements have come about in many ways — by better design through research and experience, improved fabricating techniques, and better engine power-weight ratios.

Through all this period of development, metals have been called upon to give more and more in the way of strength, increased life, reliability, corrosion resistance and ease of fabrication. Current design trends are not lessening this pressure but rather increasing it, particularly with respect to the fatigue resistance of dynamically loaded parts. In many applications the metallurgist finds the law of diminishing returns operative in his sphere. Apart from the results of long-range metallurgical research, all immediate gains in the metal performance will have to come through all branches of engineering adhering to proven practices and paying greater attention to detail.

The following recommendations are made toward eventual reduction of metal failures in aircraft.

1. Cooperation of all concerned in giving accurate and prompt reports on all failures; this to be followed by a thorough investigation and suitable corrective action. The paucity of defect or failure reports received from the field should not be used as a criterion of good maintenance.

2. Much educational work remains to be done with designers, production and maintenance personnel. Education is a prerequisite to proper and accurate reporting. The "crystallization myth", for example, is still all too prevalent in industry today.

Despite the fact that research has not yet given us complete answers to such problems as fatigue, stress corrosion and others, we do have enough information to guide us along well-tried practices. If all aircraft parts were given the respect that propellers receive, the problem would be well in hand.

3. The future need is to consolidate our present control over the highly stressed parts such as propellers and then progress systematically through the entire structure, cleaning up on the multitude of parts which still require further work on them.

4. The dividing line between the responsibility of the designer, production engineer, maintenance engineer, and metallurgist should not be drawn up rigidly, but all should cooperate wholeheartedly in this overlapping area to achieve the maximum result.

Is the Reduction of Iron Ore by Hydrogen a Commercial Possibility?

Highly Doubtful in America

REDUCTION of iron oxide by hot hydrogen gas at moderate temperatures has been proposed in patents and technical literature from time to time. For example, Harry McQuaid, in his interesting review "Ten Years in Steel" published in the January 1951 issue of *Metal Progress*, writes, when commenting on the gyrations in the scrap steel supply and price: "Recent proposals for high-temperature cracking units for natural gas which make hydrogen (and carbon black) at an extremely low cost may be one answer. Lightly briquetted, finely divided magnetite concentrates can be completely reduced at relatively low temperatures by hydrogen. This seems to offer an almost pure iron charge for the electric furnace or openhearth, and be the answer to the recurring proposals for 'direct reduction' of iron ore." It is well to remember, however, that even if a reliable source of cheap hydrogen were available there would be some rather irritating difficulties to be overcome.

The first difficulty is that the reduction of iron oxide by hydrogen is very strongly endothermic. This, unfortunately, means that large quantities of heat to supply the reaction must be transmitted by the hydrogen gas in addition to the heat required to bring the ore up to temperature. If any considerable proportion of the required heat is supplied by *external* burners,

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Yes — With New Process for Cheap Hydrogen

IT WAS interesting indeed to read Mr. Cavanagh's remarks about the direct reduction of iron ore by hydrogen. It is the usual approach to this problem: The critic assumes it is foolish to waste time in trying to reduce iron ore at temperatures around 1100° F. This, in spite of the very clear data presented by Udy and Lorig in the October 1942 issue of *Metals Technology*.

They show that the only logical and (I believe) the only practical approach to the commercial reduction of iron ore by hydrogen is to prepare a finely divided concentrate which is reacted with hydrogen at 1100° F. This will insure a 100% reduction of the iron oxide to iron in a matter of 30 to 40 min.

Mr. Cavanagh points out the difficulty of heating a reduction unit by external burners to obtain the desired temperature. To the engineer this presents no problem because all that is needed to overcome the problem of external heating is to heat internally — especially since we have in hydrogen an ideal medium because of its high specific heat. I have seen, many times, 500-lb. charges of ore brought to 1100° F. in not over 30 min. by heated hydrogen circulated through the mass. The hydrogen was heated in a special but simple heat exchanger unit and worked very well as a source of temperature control for the ore.

In the reduction, ground and loosely bri-

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Cavanagh Is Doubtful

the walls of the furnace will be much hotter than the center of the charge. This is extremely undesirable in the shaft type of furnace, since the sponge iron produced is uncommonly sticky, and the usual experience has been that the reduced material will form large clinkers which eventually shut the furnace down.

In contrast with this, reduction with carbon or carbon monoxide is not strongly endothermic and the problem of supplying heat for the reaction is not so serious. Even so, experience teaches that it is usually difficult to supply a large proportion of the heat through the walls of a shaft furnace, because of the tendency for sticking. Hence the success of the ordinary blast furnace — or at least a prime reason. A surplus of coke is mixed with the charge and burned right where its heat is needed.

An excellent practical illustration of the wide difference in conditions during reduction with hydrogen and with carbon monoxide is afforded by the method used in the Swedish Wiberg-Soderfors method to control the temperature in the reduction shaft. (See *Metal Progress*, May 1950, p. 633.) In this process the gas is about 75% CO and 25% H_2. The reaction at the bottom portion of the shaft is very slightly exothermic when the proportion of CO is as above noted. If the temperature begins to rise, there may be danger of sticking in the discharge mechanism. When the temperature starts to rise the hydrogen content of the reducing gas mixture is increased. This immediately tends to make the reaction endothermic and brings the temperature down. It also increases the production rate slightly. This simple but theoretically perfect method of temperature control in this process demonstrates in a practical manner the relative heat requirements of hydrogen and carbon monoxide reduction of iron ore. The more rapid reduction in hydrogen is bought at the expense of a great increase in heat requirements for the desired reaction.

There have been many instances where investigators have found that they completely reduced iron ore with hydrogen at low temperatures. Most of these results have been on laboratory scale and in many instances the results have been obtained on a particular size of ore particle with a particular mineralogical structure. In our investigations at Ontario Research Foundation we have found to our sorrow that such results must be regarded with interest but not much enthusiasm. I do not know of any instance where a large furnace could be oper-

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quetted iron ore concentrates were processed (according to Udy and Lorig) and no difficulty was found in obtaining 100% reduction of the briquetted charge in about 3 hr. Judging by the results with 500-lb. charges there is no reason why charges of 5000 lb. could not be completely reduced in the same time, since the time is governed by the size of the largest grain of ore and its accessibility to the hydrogen.

Mr. Cavanagh mentions that after the ore is reduced it is necessary to prevent reoxidation or contact with air. We had this same problem in wartime experiments made by Republic Steel Corp. — but only on the first run. By the simple expedient of raising the temperature in the reduction unit for a short time (5 min.) to 1650° F. and then cooling it to 200° F. max. (all by a flow of hydrogen of appropriate temperature) the other batches produced were 100% reduced and 100% stable. I have some of the reduced iron today which after four or five years is still fully metallic.

I have read much of the literature on the hydrogen and the carbon monoxide reduction of iron oxide, and I am fairly well acquainted with such attempts as the Madaras (Texas) and Republic Steel (Youngstown) efforts at ore reduction with natural gas and coke oven gas. Both of these disregarded the problem of ore concentration, particle size, and temperature effects obvious to anyone who will study Udy and Lorig's excellent presentation of this subject. I would suggest that Mr. Cavanagh should try, on any desired scale, the reduction with hydrogen of magnetite ore concentrates which have been reduced to 100 mesh and then nodulized or briquetted to any convenient size and baked. By heating the hydrogen externally to the reduction unit and stabilizing the charge at 1650° F. for 5 min. before final cooling in hydrogen he will get 100% reduction without much delay or trouble. Pressure helps; we found about 30 psi. (gage) desirable and practical. The internally heated reduction unit was well insulated.

After much careful study and contact with the direct reduction of iron ore by hydrogen to iron to compete with scrap as a steel melting furnace charge, I have come to the conclusion that there are certain fundamentals which must be followed to make this operation thoroughly practical and economical.

First — The iron ore should be a magnetite or pyrite. When ready for reduction the particles must be not coarser than 80 mesh. The ore must be concentrated, before reduction, to

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ated at a temperature lower than 1600° F. to produce any considerable tonnage of reduced iron by hydrogen reduction. Reduction certainly goes on at much lower temperatures than this, but on a commercial scale the reaction is so slow that it is impractical.

The most convincing demonstration of this commercial fact is that most annealing furnaces which perform the final annealing on iron powder in a hydrogen atmosphere operate in the range between 1450 and 1650° F. This final reduction must be performed as cool as possible to prevent the powder from sintering. At lower temperatures than these, however, the production from a furnace of practical size is very low, being of the order of one ton an hour.

It may be that, with an extremely fine particle size and an unusual ore which has a mineralogical character allowing easy access of reducing gas during all the reduction cycle, some ingenious method might be found to supply heat to the process at a sufficiently rapid rate so that reduction could be carried on at a temperature even as low as 700° F., as suggested by Mr. McQuaid in his article above quoted. I doubt that this type of process could be of much importance except for making iron powder.

Experimenters have usually found that it is one thing to reduce ore to iron particles, and another to preserve these particles in the metallic state. We have had some experience with the annoying pyrophoric tendency of sponge iron, particularly when it is fine and has been reduced at low temperature. It has been practical experience in Sweden for many years that sponge iron reduced at temperatures of 1900° F. and higher has very much less tendency to ignite in the air than sponge iron reduced at lower temperatures. Even pyrophoric sponge iron can be discharged from the reduction furnace red hot into cold water without serious reoxidation if the water contains lime.

As the supply of first-grade metallurgical coke becomes more limited, we will undoubtedly hear about many schemes to revolutionize blast furnace practice, and these will include additions to the already numerous proposals for direct iron manufacture. Present prospects in the latter effort do not look very bright. Everyone really interested should read Earle Smith's paper given before the American Iron and Steel Institute in May of 1948 ("Experience to Date on Iron Production by Methods Other Than Coke Blast Furnace"), and his later remarks in the 1950 Campbell Memorial Lecture before the

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contain not more than the desired maximum percentage of silica. The process is not self-fluxing and the alumina and silica in the ore will carry through to the melting unit (or to the compact, if the powder is used as such). In order to use direct-reduced iron to the best advantage in the basic melting furnace, the silica must be removed by concentration both before and after reduction to an amount satisfactory to the melter.

Second — The reduction of the finely divided ore should be by hydrogen and must follow the cycle indicated by Udy and Lorig. This requires a temperature of 1050 to 1100° F. for 100% reduction and minimum time. In addition it must be flash heated to 1650° F. to prevent reoxidation.

Third — Heating of the iron oxide particles must be done by the hydrogen and not by external means. This is to prevent fusing of the charge to the reduction chamber walls.

When the above fundamental requirements are met the iron oxide in the form of loosely bonded briquettes or nodules can be quickly reduced 100% to iron without difficulty and with the minimum of supervision or technical skill.

The temperatures used are relatively low, the equipment is not subjected to unusual abuse, and whatever the batch size the complete reduction and stabilizing cycle is less than 7 hr., so that three batches can be reduced per day without any great effort or expense except for hydrogen. This procedure is well established and can easily be demonstrated.

There is available a large amount of magnetite ore suitable for concentration for direct reduction but the lack of cheap hydrogen has made its use economically unattractive in spite of its desirable features, such as an extremely low sulphur and phosphorus content and ease of charging.

During the latter part of 1950 there has been worked out a new and also very simple method of cracking natural gas to obtain free carbon (colloidal) and hydrogen. Each ton of iron reduced requires 22,000 cu.ft. of hydrogen and this in turn requires 11,000 cu.ft. of natural gas (plus extra fuel needed to obtain the required cracking temperature). Each 11,000 cu.ft. unit of natural gas when cracked will produce 350 lb. of pure finely divided carbon having a sales value of at least 1¢ per lb.

There is no doubt in my mind that Earle Smith's statement (that the reduction of iron ore by carbon in the openhearth is the simplest and

in Chicago last fall. These papers had all the devastating effects of a cavalry charge. Practically everything in sight was hacked to pieces and to those who have not become infected with the peculiar brand of sympathetic enthusiasm necessary for serious consideration of many sponge-iron processes, there was nothing left alive in the whole sponge-iron field.* His conclusion was that the basic openhearth furnace is the best machine for *direct* reduction, being easily capable of reducing 300 lb. of iron from ore per net ton of ingots poured. The fly in the ointment here is that a special "charge" ore is needed, and it is none too available.

I think that Earle Smith did a great service in clearing the field; nevertheless we feel that it is imperative to give serious consideration to any new suggestion which is fundamentally sound and gives any promise of a radical departure from present methods of reducing iron ore.

*Editor's Footnote — Unfavorable facts, however, do not deter the plausible promoter. Government money is being sought to put a World-War-II-baby plant into such shape that it can "produce" 10,000 tons of sponge iron a day. Why should it need lush governmental financing if there were much chance it could survive in competition with conventional processes?

best mechanism) is a logical and easily proven one, but this process also has its limitations, since ore is added to the openhearth primarily to reduce carbon from the hot metal. The economics of such a reduction is tied in with the relative price of scrap and hot metal, and if we figure the cost of charge ore, pig iron, fuel and repairs incidental to an operation where a maximum of ore and pig iron is on the openhearth charge, it may not turn out to produce steel as cheaply as though a larger proportion of low-carbon steel scrap (or direct iron) were melted in the first place.

As a matter of fact, the openhearth is really secondary to the electric furnace in the reduction of iron oxide by carbon, since the electric can and does operate at a higher bath temperature and can carry much higher iron oxide in the slag. These two factors primarily govern the reaction rate of iron oxide and carbon, as every melter knows.

Let me close with my conviction that the solution of such an engineering problem as this will not come by working desperately for many hours on the byways and alleys of detail, but by sitting back and thinking out the few basic, simple fundamentals.

Library Use of New Indexing System

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The division of Metallurgical Research of the Kaiser Aluminum and Chemical Corp. is an organization three years old. Shortly after its inception, plans were laid for the collection of books, periodicals, and reports into a research and reference library.

At about the time this library began to take shape, a new outline for classifying metallurgical literature by subject was developed jointly by the American Society for Metals and the Special Libraries Association. The system is designed for use with a punched-card file, as well as with orthodox library methods. The punched-card index was deemed more feasible for a special library such as the one we had in prospect than the older, established methods of cross-indexing on separate cards, and its installation and use were consequently begun in July 1950 under the supervision of Miss Alvina Wassenberg, research librarian.

The ASM-SLA system* was adopted for the indexing of all reports on research work conducted in the Division as well as supplemental information contained in published papers related to similar projects. Thus the punched cards in the Kaiser library now include references to preprints of papers from many engineering societies, and government reports such as those emanating from the Bureau of Standards, the U. S. Bureau of Mines, the N.A.C.A., and the Air Force. More than 700 miscellaneous reports and photostatic reproductions of published articles, which have been added to the working shelves of the library at the request of staff investigators, are also adequately indexed on the punched cards.

No attempt has been made to code books and past-periodical compilations which were already catalogued according to the Library of Congress method. The punched cards would have become overloaded with the quantity of cross-filed information printed in books. Efficiency of the cards would be reduced without any concrete improvement in indexing.

As a further safeguard against overloading the cards with extraneous material of small value, research staff members help the librarian to select published articles and abstracts for inclusion. When publications enter the library, the librarian scans them and notes the code designation of each article for which she plans to prepare a card. Then, as these publications are circulated through the staff, each investigator and department head has an opportunity to suggest revisions or additions. A number of the booklets containing the classification outline are available so that each investigator or department head can use them to suggest indexing headings or coding symbols. At least one "Work Book" is also provided in each department. (The Work Book is a set of looseleaf sheets containing the standard classification headings and subheadings, so arranged that additions or revisions can be readily made to suit individual needs.)

When an investigator comes upon an article which he feels will be of value, especially in his own field of research, he looks up the proper coding in the Work Book and jots it down in the margin of the first page of the article. Then in a note attached to the periodical, he requests that the library prepare a punched card properly indexed and carrying an abstract of the subject matter.

The same procedure is followed for abstract bulletins also, thus providing a double check on articles appearing in journals to which the library subscribes. Figure 1 shows a page in an abstract bulletin with code annotations in the margin and a card punched and abstracted accordingly. Adding of published abstracts to the card file helps greatly to broaden the coverage of subjects of particular interest to research investigators in the Division.

Occasionally, an investigator finds that the standard classification outline does not ade-

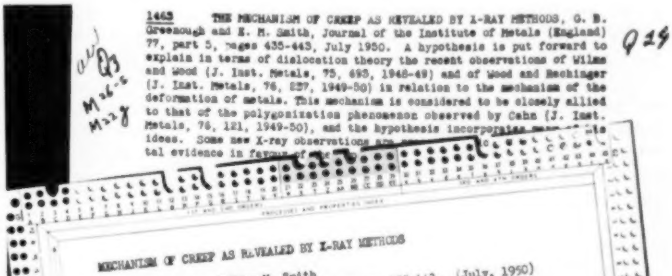

Fig. 1 — Page From an Abstract Bulletin With Code Notations in Margin and Punched-Card Slotted Accordingly

*"ASM-SLA Metallurgical Literature Classification", American Society for Metals, Cleveland.

"How to Find Detailed Information When You Want It", by A. H. Geisler, *Metal Progress*, May 1950, p. 613.

"New Classification Outline Gives First Complete Breakdown of Metallurgical Field", *Metals Review*, February 1950, p. 4.

quately index a particular article or report. When this occurs, he discusses the matter with the head of his department, and the two of them select a new subheading to meet their needs, decide under which of the main classification headings it belongs, and submit their suggestions for expansion of the index to the librarian for her final approval. The new subheading is then entered in all copies of the Work Book.

For example, several new classifications were needed in connection with remelt studies. In the aluminum industry, alloying and ingot casting are not considered part of the refining process as they are in some other nonferrous industries. The nature of remelt practices indicated that they could be added best to the section of the "Processes and Properties" index designated "E — Foundry". Three new subheadings were therefore entered in the Work Book — namely, "E7. Ingot Casting", "E8. Fluxes and Fluxing", and "E9. Alloying". This change was the only major adaptation necessary to make the classification outline compatible with aluminum research.

Because of the uncertainty of fields and phases of research in which the Division will be engaged ten years hence, it was deemed advisable to minimize the use of fourth-order indexing and new headings. Fourth-order divisions are added only when unavoidable, consequently there is still much room for expanding the system.

The "Materials Index" section of the classification provides a good breakdown for coding aluminum alloys. With the addition of alloy K-150 as "Alg34", this section is adequate to cover most existing commercial alloys. The "Common Elements Index", however, is used to classify experimental alloys according to their chemical compositions, as well as for other metals and alloys that have no commercial designation provided in the standard index.

The "Common Variables Index" has many uses, as its name implies. It may be used to code information on the construction and use of specialized laboratory equipment, or to separate reports on different phases of a research program according to the influence of various factors. Although the entire section will be used eventually, the divisions which are currently finding most use are those numbered 1, 2, 3, 4, 10, 11, and 12 (equipment and processes, influencing factors, wrought metal forms, type of literature, form of literature, and language). One of the most notable advantages of this section is in the handling of patents and patent information. Not only is it simple to find quickly all references to patents in a particular field, but it is also possible, by adding a subhead, to catalog all former patent searches.

All reports in the library, whether prepared in the laboratories, by government agencies or other outside sources, are filed in numerical order in vertical files with the number of each report noted on its corresponding punched card. Cards which refer to articles in journals kept in the library indicate the issue, volume, and page where the article can be located. These journals are stacked on the library shelves in alphabetical order. Cards which relate to abstracts also contain page and volume guides to the abstract compilations, which are arranged on the shelves in the customary chronological order. Thus, the librarian can readily locate any pertinent data which has been coded on a given subject within a few minutes after an investigator requests it.

The system is working out well, except for a few weaknesses which have cropped up in the classification outline. These can be remedied by additions made at the user's discretion. One of these weaknesses from our standpoint is the lack of provision in the system for material pertaining to the chemical end of metal production and research. Some phases of metals chemistry can be readily coded in the existing sections; quite a few cannot. A few examples of these pertaining to the aluminum industry are: Carbon studies (related to the electrolytic reduction of alumina), cryolite as used in the same process, and froth flotation reagents used in ore dressing and reclamation work. Another weakness, as previously pointed out, lies in the absence of code designations peculiar to the remelt practices of aluminum production.

The greatest problem of all is expected to arise within a few years, when the number of cards becomes too unwieldy for a complete needling of all cards each time some particular reference is sought. The librarian plans to divide the cards along the lines of the first-order divisions of the "Processes and Properties" index when the volume of coded material becomes unhandy. This should break up the single mass into approximately 20 smaller groups of cards, and it is expected that the efficiency of the system will remain as great as it is at the present time and that it might even be improved. Some (a relatively few) cards may have to be duplicated where the subject matter applies to more than one main heading.

Although less than a year has elapsed since the installation of this system, the librarian is quite satisfied with it and feels that it will serve well in its intended sphere.

DUCTILE IRON

A Revolutionary Metallurgical Development

DUCTILE IRON is a cast ferrous product which combines the *process advantages* of cast iron with many of the *product advantages* of cast steel.

No longer in the pilot-plant stage, this new material is now produced and sold on the basis of specifications. Not only are its individual properties exceptional, but no other common engineering material provides such a combination of excellent castability and fluidity, with high strength, toughness, wear resistance, and machinability.

Actually, "ductile iron" denotes not a *single* product, but rather a family of ferrous materials characterized by graphite in the form of spheroids . . . a form controlled, in a broad sense, by small amounts of magnesium. Presence of spheroidal rather than flake graphite gives this new product a ductility that is unique among gray cast irons.

Four important types of ductile iron now being produced commercially are tabulated below.

REPRESENTATIVE MECHANICAL PROPERTIES OF COMMERCIAL HEATS OF DUCTILE IRON

	Grade	Tensile strength, psi	Yield strength, psi	Elongation per cent	BHN	Usual condition
A	90-65-02	95/105000	70/75000	2.5/5.5	225/265	As-cast
B	80-60-05	85/95000	65/70000	5.5/10.0	195/225	As-cast
C	60-45-15	65/75000	50/60000	17.0/23.0	140/180	Annealed
D	80-60-00	85/95000	65/75000	1.0/3.0	230/290	As-cast

A Pearlitic in structure. Provides good mechanical wear resistance.

B Pearlitic-ferritic in structure. Provides strength and toughness combined.

C A fully ferritic structure usually obtained by short anneal of either (A) or (B). Provides optimum machinability and maximum toughness.

D Higher phosphorous content than preceding grades, also higher manganese. Provides high strength and stiffness, but only moderate impact strength.

SOME UNIQUE PROPERTIES OF DUCTILE IRON

1. Its elastic modulus, about 25,000,000 psi, is virtually unaffected by composition or thickness . . .

2. It can provide a chilled, carbidic, abrasion-resistant surface supported by a ough ductile core. No other single material can combine these properties . . . its only counterpart being a tough material coated with a hard welded overlay.

3. As-cast ductile iron of 93,000 psi tensile strength has the same machinability rating as gray iron with a strength of 45,000 psi.

4. Annealed ductile iron can be machined at a rate 2 to 3 times that of good quality gray iron.

5. It can be satisfactorily welded.

APPLICATIONS

Automotive, agricultural implement, railroad and allied industries apply ductile iron, as-cast and heat treated, in components too numerous to detail.

Machinery, machine tools, crankshafts, pumps, compressors, valves and heavy industrial equipment such as rolls and rolling mill housings, utilize its high strength and rigidity.

In scores of engine, furnace and other parts serving at elevated temperatures, it provides oxidation and growth resistance heretofore unavailable in high carbon castings.

Other applications include paper, textile and electrical machinery, marine equipment, and pipe.

AVAILABILITY

Send us details of your prospective uses, so that we may offer a list of sources from some 100 authorized foundries now producing ductile cast iron under patent licenses. Request a list of available publications on ductile iron . . . mail the coupon now.

EMBLEM OF INCO SERVICE

The International Nickel Company, Inc.
Dept. MP, 67 Wall Street
New York 5, N. Y.
Please send me a list of publications on:

DUCTILE IRON

Name ______________ Title______

Company ______________________

Address ______________________

City ______________ State______

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

Heat Treatment of Age Hardenable High-Nickel Alloys*

Development & Research Division, The International Nickel Co., Inc.

Alloy	Treatment	Material Condition	Metal Temperature °F.	Time at Temperature*	Rate of Cooling*	Furnace Atmosphere
"K" Monel, "KR" Monel and Duranickel	Anneal for softening	Cold worked	1600	2 to 5 min.	Preferably quench; quenching mandatory for sections over ½ in. (a)	Reducing; sulphur-free; use dry hydrogen for bright annealing
			1800	1 to 3 min.		
	Age hardening	Soft (hot rolled, annealed, cold drawn over 1½ in. diam.)	1080 to 1100	16 hr. (b)	Average 15 to 25° per hr. down to 900° F. Cooling may be in steps of 100° F., holding furnace 4 to 6 hr. at each step.* For example, if soaking was at 1100° F., drop temperature to 1000° F. for 4 to 6 hr., then to 900° F. for 4 to 6 hr., then shut down*	Use hydrogen or cracked ammonia for semibright hardening, otherwise use a sulphur-free atmosphere. Cool to 400° F. before removing from protective atmosphere
		Moderately cold worked (cold drawn to 1½ in. diam., half-hard strip and wire, cold upset parts)	1080 to 1100	8 to 16 hr. (c)		
		Fully cold worked (full-hard wire and strip, springs)	980 to 1000	6 to 10 hr. (c)		
	Stress equalizing	Material cold worked after age hardening, such as coil springs. Also used on cold worked parts which are not to be age hardened	575 to 650	1 to 2 hr.	Quench or furnace cool	Use reducing atmosphere if tarnish is to be avoided
Permanickel	Anneal for softening	Cold worked	1600	2 to 5 min.	Preferably quench; quenching mandatory for sections over ½ in. (a). Sections must be quenched for subsequent age hardening	Reducing; sulphur-free; use dry hydrogen for bright annealing
			1800	1 to 3 min.		
			2000 (d)	1 to 2 min.		
	Age hardening	Soft (hot rolled, annealed, cold drawn over 1½ in. diam.)	910 to 930	16 hr. (b)	Cooling rate is not important; work can be quenched (a), air cooled, or furnace cooled	Use hydrogen or cracked ammonia for semibright hardening, otherwise use a sulphur-free atmosphere. Cool to 400° F. before removing from protective atmosphere
		Moderately cold worked (cold drawn to 1½ in. diam., half-hard strip and wire, cold upset parts)	900 to 920	8 to 16 hr. (c)		
		Fully cold worked (full-hard wire and strip, springs)	890 to 910	6 to 8 hr. (c)		
	Stress equalizing	Material cold worked after age hardening, such as coil springs. Also used on cold worked parts which are not to be age hardened	575 to 650	1 to 2 hr.		Use reducing atmosphere if tarnish is to be avoided
"S" Monel	Softening	As-cast	1600	1 hr.	Must be quenched (e)	Reducing; sulphur-free; use dry hydrogen for bright annealing
	Age hardening	Soft	1100	4 to 6 hr.	Furnace cool	Use hydrogen or cracked ammonia for semibright hardening, otherwise use a sulphur-free atmosphere. Cool to 400° F. before removing from protective atmosphere
Inconel "X"	Anneal for softening	Cold worked	1900 to 2000	15 to 30 min.	Preferably quench; quenching mandatory for sections over ½ in. (a)	Reducing; sulphur-free; use dry hydrogen for bright annealing
	Solution treatment (f)	Any	2075 to 2125	2 to 4 hr.	Quench	
	High-heat stress equalizing (g)	Any	1600 to 1650	24 hr.	Air cool	Use reducing atmosphere if tarnish is to be avoided
	High-heat aging (h)	Any	1525 to 1575	24 hr.	Air cool	Use hydrogen or cracked ammonia for semibright hardening, otherwise use a sulphur-free atmosphere. Cool to 400° F. before removing from protective atmosphere
	Low-heat age hardening	Soft (hot rolled, annealed, cold drawn over 1½ in. diam.)	1300	20 hr.	Air cool or furnace cool	
		Moderately cold worked (cold drawn to 1½ in. diam., half-hard strip and wire, cold upset parts)	1300	20 hr.		
		Fully cold worked (full-hard wire and strip, springs)	1200 (b)	4 hr.		
			1350 (i)	16 hr.	Air cool	
	Low-heat stress equalizing	Material cold worked after age hardening, such as coil springs. Also for cold worked parts not to be age hardened	650 to 900	1 to 2 hr.	Quench or furnace cool	Use reducing atmosphere if tarnish is to be avoided

***For parts not requiring maximum hardness, cooling from solution heat treatment may be less rapid and aging time shortened.**

(a) Quench in 2% solution of alcohol in water to reduce superficial oxide.

(b) For maximum room-temperature properties.

(c) The longer time for softer material; the shorter time for harder material.

(d) Necessary for subsequent age hardening.

(e) If section is intricate, air cool to 1200° F. and then oil quench.

(f) Necessary for subsequent age hardening to develop maximum strength at 1200 to 1500° F.

(g) For subsequent aging to develop maximum strength at temperatures up to 1100° F.

(h) Necessary for subsequent aging to develop optimum strength and ductility at 1200 to 1500° F.

(i) For applications at 650° F. and higher.

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Age Hardenable High-Nickel Alloys

DEVELOPMENT of age hardenable, high-nickel alloys began in 1924 with the discovery that additions of small amounts of aluminum to Monel metal produced a new alloy,† "K"* Monel, which could be hardened by heat treatment‡ without significant change in the corrosion resisting characteristics of the base alloy, and that this thermal treatment could be combined with cold work to develop strengths and hardnesses equivalent to alloy steels. Later, additions of titanium were made to "K" Monel to improve both its age hardening and its hot malleability.††

Today, five wrought alloys have been patented and produced by The International Nickel Co., Inc.—"K" Monel, "KR"* Monel, Duranickel,* Permanickel* and Inconel "X"* — and one cast alloy, "S"* Monel. Each has good corrosion resistance and may be hardened to high levels of strength and hardness by aging at moderate temperatures. Their response to heat treatment reverses that of steel: They are soft when quenched, and relatively hard when cooled slowly. They age like duralumin and beryllium-copper, but (unlike duralumin) the high-nickel alloys can be cooled slowly after aging at moderately elevated temperatures.

"K" Monel is a nickel-copper-aluminum alloy containing approximately 2.75% aluminum. Its strength and hardness, particularly in large sections, are comparable with those of heat treated alloy steels, and its resistance to corrosion is similar to that of Monel.

"KR" Monel is the same as "K" Monel except for a nominal carbon content of 0.25% to provide improved machinability.

"S" Monel is a cast nickel-copper-silicon alloy containing approximately 4% silicon which hardens it to about 350 Brinell and imparts resistance to galling and erosion.

Duranickel is a nickel-aluminum alloy with greater strength and hardness than "K" Monel, accompanied by the high resistance to corrosion characteristic of nickel.

Permanickel is a high-nickel alloy having mechanical properties and resistance to corrosion similar to Duranickel, and good electrical and thermal conductivity.

Inconel "X" is a nickel-chromium-iron-titanium alloy having a low creep rate under high stresses at 1200 to 1500° F. and highly resistant to chemical corrosion and oxidation.

Nominal chemical compositions, physical constants and mechanical properties of the alloys are summarized in Table I.

The usual heat treatments are softening, age hardening, and stress equalizing. The temperatures required vary with the composition of the alloys. The treatments are summarized in Table IV and described in detail later.

Softening occurs during heating at 1600 to 2000° F. for 2 min. to 2 hr. and quenching in water (or a 2% solution of denatured alcohol to facilitate subsequent pickling). It is necessary to quench Permanickel for subsequent age hardening; the other alloys can be age hardened if cooled in air from the softening treatment. Figure 1 indicates the temperature and time for this operation. (The middle graph, for Duranickel can also be used for Permanickel if softening only, and not subsequent aging, is required.)

Age hardening of "K" Monel, "KR" Monel, "S" Monel and Duranickel is accomplished by heating at 1000 to 1100° F.; Permanickel requires heating at 890 to 930° F., and Inconel "X" at 1300 to 1350° F. For uses of Inconel "X" where maximum creep strength at 1200 to 1500° F. is imperative, another treatment will be given later.

To obtain maximum properties, aging must

*Reg. U. S. Patent Office.

†"Aluminum-Copper-Nickel Alloys of High Tensile Strength Subject to Heat Treatment", by W. A. Mudge and P. D. Merica, *Transactions*, A.I.M.E., Vol. 117, 1935, p. 265-276.

‡W. A. Mudge, U. S. Patents No. 1,755,554,-5,-6,-7.

††C. G. Bieber and M. P. Buck, U. S. Patent No. 2,234,955.

Table I — Nominal Properties of the Alloys

	"K" Monel	"KR" Monel	"S" Monel	Duranickel	Permanickel	Inconel "X"
Nominal Chemical Composition						
Nickel *(a)*	66.	66.	63.5	93.7	98.5	73.
Copper	29.	29.	29.5	0.05	0.03	0.05
Iron	0.9	0.9	2.	0.35	0.1	7.
Manganese	0.75	0.75	0.8	0.3	0.2	0.5
Silicon	0.5	0.5	4.	0.5	0.15	0.4
Chromium	—	—	—	—	—	15.
Carbon	0.15	0.25	0.1	0.17	0.25	0.04
Columbium	—	—	—	—	—	1.
Aluminum	2.75	2.75	—	4.4	—	0.9
Titanium	0.5	0.5	—	0.4	0.4	2.5
Physical Constants						
Density g./cc.	8.47	8.47	8.36	8.26	8.75	8.3
lb./cu.in.	0.306	0.306	0.302	0.298	0.316	0.3
Melting range, °F.	2400/2460	2400/2460	2300/2350	2500/2620	2550/2620	2540/2600
Specific heat *(b)*	0.127	0.127	0.13	0.104	0.106	0.105
Expansion *(c)*	7.8	7.8	6.8	7.2	7.2	7.6
Heat conductivity *(d)*	130	130	180	137	400	87
Resistivity *(e)*	350	350	380	260	94.5	750
Curie point *(f)*	−150	−150	−70	200	560	−280
Modulus, psi.						
Tension	26,000,000	26,000,000	24,200,000	30,000,000	30,000,000	31,000,000
Torsion	9,500,000	9,500,000	—	11,000,000	11,000,000	11,000,000
Poisson's Ratio	0.32	0.32	—	0.31	0.31	—
Tensile Properties of Rods *(g)*						
As cast						
Yield	—	—	80/115	—	—	—
Tensile	—	—	120/145	—	—	—
Elongation	—	—	4/1	—	—	—
Brinell	—	—	275/350	—	—	—
Annealed condition						
Yield	40/60	40/60		30/60	30/60	45/60
Tensile	90/110	90/110	—	90/120	90/120	110/130
Elongation	45/25	45/25	—	55/35	55/35	50/40
Brinell	140/185	140/185	175/260	135/185	135/185	150/215
Rockwell	B-75/90	B-75/90	—	B-75/90	B-75/90	B-95 max.
Annealed and age hardened						
Yield	90/110	90/110	80/115	110/140	110/140	120/140 *(h)*
Tensile	130/160	130/160	120/145	150/190	150/190	175/200 *(h)*
Elongation	30/20	30/20	4/1	30/20	30/20	30/20 *(h)*
Brinell	250/300	250/300	300/375	285/360	285/360	300/400 *(h)*
Rockwell	C-23/32	C-23/32	—	C-30/40	C-30/40	C-33/44 *(h)*
Cold drawn and age hardened						
Yield	95/130	95/130		125/175	125/175	190/230 *(i)*
Tensile	135/180	135/180		170/210	170/210	230/270 *(i)*
Elongation	30/15	30/15		25/15	25/15	15/5 *(i)*
Brinell	265/340	265/340		300/380	300/380	
Rockwell	C-27/35	C-27/35		C-32/42	C-32/42	C-40/50 *(i)*

(a) Includes a small amount of cobalt. Alloys also contain traces of sulphur — on the order of 0.010%.

(b) B.t.u. per lb. per °F. for the range 70 to 750° F.

(c) Mean coefficient of thermal expansion per °F. $\times 10^{-6}$ for the range 70 to 212° F.

(d) B.t.u. per sq.ft. per hr. per °F. per in. for the range 70 to 212° F.

(e) Ohms per circular-mil-foot at 68° F.

(f) For age hardened condition, °F.

(g) Wire and strip which have been cold drawn or cold rolled 50 to 65% will have higher strengths and hardnesses and correspondingly lower elongations. Yield strength is range of stress at 0.2% elongation in units of 1000 psi. Tensile strength is expected range in 1000 psi. Elongation is % in 2 in.

(h) Aged at 1300° F. If quenched from 2100° F., aged at 1550° F. and again at 1300° F. the respective values are lower: 90/105, 150/170, 30/20, 260/340 and C-26/37.

(i) Figures are for strip.

be followed by controlled cooling. Mechanical properties which are 5 to 10% lower than the maxima will result from furnace cooling following aging. The correct temperature and time to be used in hardening will vary according to the initial temper of the materials. These alloys should not be heated above the specified temperature, otherwise some softening will result. Figures 2, 3 and 4 give the conditions. Hardness developed in Permanickel is the same as in Duranickel; however, the temperature should be 910 to 930° F.

Stress Equalizing, which is applied to cold worked materials for spring purposes, is accomplished by heating at 575 to 850° F.

Age Hardening for Maximum Properties

"K" and "KR" Monel — *(a)* Soft "K" Monel and "KR" Monel (about 140 to 180 Brinell, Rockwell B-75 to 90) are hardened by holding for 16 hr. at 1080 to 1100° F., followed by furnace cooling at a rate of 15 to 25° F. per hr. down to a temperature of 900° F.; or by the step treatment to be described later. Cooling from 900° F. to room temperature may be carried out by furnace or air cooling, or by quenching, without regard to cooling rate.

This procedure is suitable for as-forged and quenched or annealed forgings, for annealed or hot rolled rods and large cold drawn rods (over 1½ in. diameter) and also for soft-temper wire and strip.

(b) Moderately cold worked "K" Monel and "KR" Monel (175 to 250 Brinell, Rockwell C-8 to 25) are hardened by holding 8 hr. or longer at 1080 to 1100° F., followed by cooling to 900° F. at a rate of 15 to 25° F. per hr. Higher hardnesses may be obtained by holding for as long as 16 hr. at temperature, particularly if the materials have been only slightly cold worked.

As a general rule, those materials having an initial hardness of only 175 to 200 Brinell should be held the full 16 hr. Materials close to the top figure of 250 Brinell, or C-25, should attain full hardness in 8 hr. This procedure is applicable to cold drawn rods, half-hard strip, cold upset pieces and intermediate-temper wire.

(c) Fully cold worked "K" Monel and "KR" Monel (250 to 325 Brinell, C-25 to 35) are hardened by holding at 980 to 1000° F. for 6 hr. or longer, followed by cooling to 900° F. at a rate of 15 to 25° F. per hr. In some instances slightly higher hardnesses may be obtained (particularly with material near the lower end of the hardness range) by holding 8 or 10 hr. at temperature. This procedure is suitable for spring-temper strip, spring wire, or heavily cold worked pieces such as small, cold formed balls. Figure 2 illustrates the procedures.

Treatment for Machinability — "KR" Monel for optimum machinability should be heated at 1500 to 1550° F. for 2 to 4 hr. and quenched in water. If subsequent age hardening is desired, the procedures in *(a)* above should be followed.

"S" Monel, as-cast (325 Brinell), or soft (240 Brinell), as a result of heating at 1600° F. for 1 hr., air cooling to 1200° F., and quenching in oil, is hardened by holding 4 hr. at 1080 to 1100° F., followed by furnace cooling. Controlled cooling, as for "K" Monel and Duranickel, is not necessary. The aging treatment produces hardness in the quenched and aged alloy as high as, or higher than that of the as-cast and aged alloy,

Table II — Short Aging Treatments for "K" Monel

Condition	Aging		Tensile			C-Scale Hardness
	Temp.	Hr.	2% Offset	Ultimate	Elon. in 2 In.	
Rod	0	0	45	93	44	157
hot rolled	1100	2	82	132	36	17
	1100	4	86	136	34	20
	1100	8	90	142	33	22
Strip	0	0	50	100	39	3
annealed	1100	2	90	142	31	24
	1100	4	96	141	27	25
	1100	8	98	140	27	26
Strip	0	0	90	111	27	19
cold rolled 10%	1100	2	122	155	23	31
	1100	8	123	156	21	31
	1000	2	124	141	24	31
	1000	8	129	149	22	32
Strip	0	0	115	125	14	23
cold rolled 20%	1100	2	140	163	18	34
	1100	8	141	163	18	33
	1000	2	143	169	17	34
	1000	8	148	174	18	35
Strip	0	0	136	143	5	27
cold rolled 40%	1100	2	159	175	14	37
	1100	8	156	174	14	36
	1000	2	165	182	11	37
	1000	8	167	184	13	38
Strip	0	0	141	148	4	29
cold rolled 50%	1100	2	166	179	12	38
	1100	8	161	177	13	38
	1000	2	173	187	10	39
	1000	8	174	189	11	39

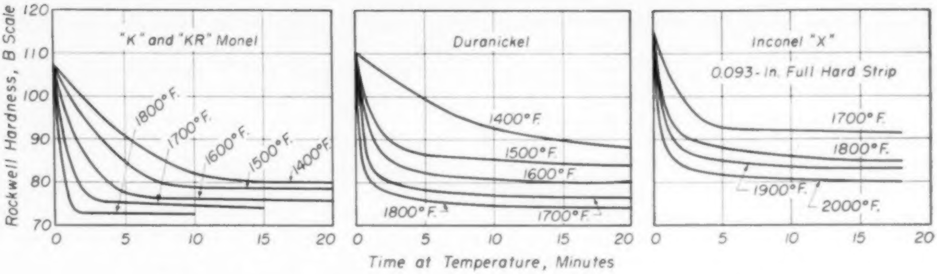


Fig. 1 — Approximate Time Required at Various Temperatures to Produce a Given Hardness in Nickel Alloys. The data for these figures were obtained on specimens which had been water quenched from the softening heat

and mechanical properties of the same order as the as-cast material.

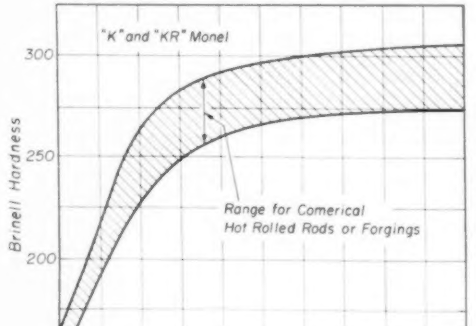
Duranickel — *(a)* Annealed Duranickel (135 to 185 Brinell, B-75 to 90) is hardened by holding for 16 hr. at 1080 to 1100° F., followed by furnace cooling at a rate of not more than 15° F. per hr. down to a temperature of 900° F.; or by the "step" treatment. Cooling from 900° F. to room temperature may be carried out by furnace or air cooling, or by quenching, without regard to the cooling rate. This procedure is suitable for forgings, annealed or hot rolled rods, large cold drawn rods (over 1½ in. diameter), and annealed wire or strip.

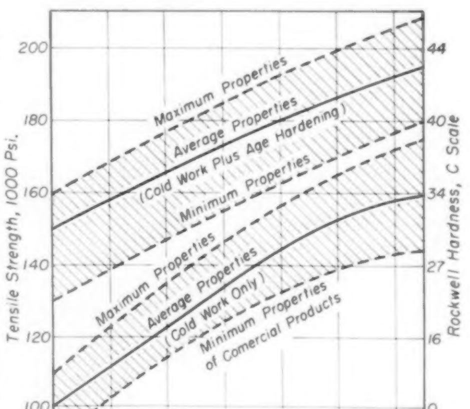
(b) Moderately cold worked Duranickel (185 to 250 Brinell, Rockwell C-8 to 25) is hardened by holding for 8 hr. or longer at 1080 to 1100° F., followed by cooling to 900° F. at a rate not exceeding 15° F. per hr. Higher hardnesses may be obtained by holding it for as long as 16 hr. at temperature, particularly if the material has been cold worked only slightly. As a general rule, material having an initial hardness of only 185 to 200 Brinell (C-8 to 13) should be held the full 16 hr.; material having an initial hardness of approximately 250 Brinell (C-25) should attain full hardness in 8 hr.

This procedure is applicable to cold drawn rods, half-hard strip, cold upset pieces and intermediate-temper wire.

(c) Fully cold worked Duranickel (260 to 350 Brinell, Rockwell C-26 to 38) is hardened by holding at 980 to 1000° F. for 6 hr. or longer, followed by cooling at a rate not exceeding 15° F. per hr. In some instances, slightly higher hardnesses may be obtained, particularly with material near the lower end of the hardness range, by holding 8 or 10 hr. at temperature. This procedure is suitable for spring-temper strip, spring wire or heavily cold worked pieces such

Fig. 2 — Age Hardening of "K" and "KR" Monel, as It Varies With Time and Degree of Cold Work





as small, cold formed balls. Figure 3 illustrates the procedures.

Permanickel is hardened by a double treatment, but usually only the second operation is required, the first usually having been carried out by the producer prior to the final stages of manufacture. The first operation is a high-temperature "solution" treatment, a quench from 2000° F. Material purchased "in condition to respond to heat treatment" will have been given this treatment. If for any reason it has been heated to above 900° F. during fabricating operations, it will be necessary to repeat the "solution" treatment before it will respond to hardening. The hardening operation is similar to that used for Duranickel and illustrated in Fig. 3. Slow cooling, required by "K" Monel and Duranickel, is not necessary for Permanickel.

(a) Soft Permanickel (140 to 180 Brinell, Rockwell B-75 to 90) is hardened by holding for 16 hr. at 910 to 930° F., followed by furnace cooling or quenching. This procedure is applicable for forgings, annealed or hot rolled rods, and large cold drawn rods (over 1 in. diameter). The same treatment is used for soft strip or wire.

(b) Moderately cold worked Permanickel (200 to 300 Brinell, Rockwell C-15 to 31) is hardened by holding at 900 to 920° F. for at least 8 hr., and furnace cooling or quenching. Additional hardness results from holding as long as 16 hr. at temperature, near the lower limits of the hardness range. This procedure is applicable for small, cold drawn rods (up to 1 in. diameter), half-hard strip, cold upset articles, and intermediate-temper wire.

(c) Fully cold worked Permanickel (290 to 375 Brinell, Rockwell C-30 to 40) is hardened by holding at 890 to 910° F. for 6 hr. Increasing the time up to 8 hr. will be beneficial in instances where the original hardness is near C-30. Hard drawn wire can be age hardened fully in 4 to 5 hr. This procedure is applicable for full-hard strip, spring-temper wire, and heavily cold worked parts, such as small, cold formed balls.

Inconel "X" — *(a)* To produce the optimum combination of strength and ductility for use above 1100° F., soft or hot finished Inconel "X" (140 to 298

Table IV — Short Aging Treatments for Inconel "X" Rod

Condition	Aging		Tensile			C-Scale Hardness
	Temp.	Hr.	2% Offset	Ultimate	Elon. in 2 In.	
Hot rolled, solution treated*	1300	0	73	140	34	22
	1300	1	87	153	24	27
	1300	2	91	159	26	28
	1300	5	96	162	18	31
	1300	10	98	167	22	32
	1300	20	100	166	21	32
Hot rolled, equalized†	1300	0	77	143	36	23
	1300	1	110	169	29	33
	1300	2	114	173	28	34
	1300	5	120	179	26	36
	1300	10	125	181	25	36
	1300	20	125	182	23	37

*4 hr. at 2100° F., aged 24 hr. at 1500° F. †4 hr. at 1625° F.

Table III — Short Aging Treatments for Duranickel

Condition	Aging		Tensile			C-Scale Hardness
	Temp.	Hr.	2% Offset	Ultimate	Elon. in 2 In.	
Rod hot rolled	0	0	40	102	47	150
	1100	2	102	156	34	25
	1100	4	108	164	32	28
	1100	8	113	168	31	30
Strip annealed	0	0	47	104	42	4
	1100	2	105	159	33	30
	1100	4	112	164	30	32
	1100	8	114	167	28	32
Strip cold rolled 10%	0	0	93	118	27	21
	1100	2	124	171	24	34
	1100	8	130	172	23	35
	1000	2	119	166	26	33
	1000	8	129	178	23	35
Strip cold rolled 20%	0	0	119	132	16	26
	1100	2	146	182	19	37
	1100	8	150	184	18	37
	1000	2	142	182	21	36
	1000	8	149	190	20	38
Strip cold rolled 40%	0	0	149	154	5	31
	1100	2	178	202	15	40
	1100	8	173	195	14	39
	1000	2	171	198	15	40
	1000	8	182	209	14	42
Strip cold rolled 50%	0	0	153	158	4	33
	1100	2	186	208	14	41
	1100	8	180	198	12	40
	1000	2	187	208	14	42
	1000	8	191	214	13	42

Brinell) is first heated at 2100° F. for 2 to 4 hr. and air cooled (solution treatment); then reheated to 1550° F. for 24 hr. and air cooled (high-temperature aging); and finally reheated to 1300° F. for 20 hr. and air cooled (low-temperature aging).

(b) To produce optimum combination of strength and ductility for uses up to 1100° F., soft or hot finished Inconel "X" is heated at 1625° F. for 24 hr., furnace cooled to 1300° F., held for 20 hr. and air cooled.

An alternate procedure is to air cool after 24 hr. at 1625° F., reheat to 1300° F. for 20 hr.

(c) Soft or moderately cold worked sheet, strip and wire (B-80 to 100) for use at temperatures up to 1000° F. are hardened by heating at 1300° F. for 20 hr. and air cooling.

(d) Springs, wire or strip, cold worked 40 to 65% for use up to 800° F., are hardened by heating at 1200° F. for 4 hr. and air or furnace cooling.

Hardening for Intermediate Properties

Sometimes it may be desired to age harden the material to less than the maximum. This can be done by decreasing the aging temperature, the holding time, and the cooling rate for maximum hardness.

It would be difficult to establish a single procedure that will always be satisfactory. The data summarized in Tables II to V show the results from aging at lower temperatures up to 8 hr. and air cooling. 90% or more of the maxima values can be obtained in 4 hr. with hot rolled or annealed material, and in 2 hr. with heavily cold worked. In the case of annealed and lightly cold worked material, normal furnace cooling after the 4-hr. aging treatment will give slightly higher values than air cooling

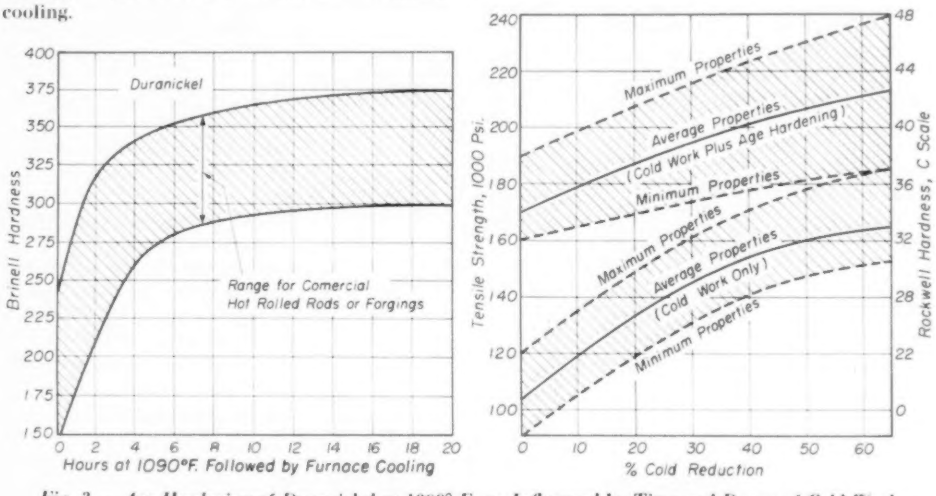


Fig. 3 — Age Hardening of Duranickel at 1090° F. as Influenced by Time and Degree of Cold Work. Above curves are approximately correct for Permanickel if aging is conducted at 910 to 930° F.

because of the extra time the alloy is above 900° F. Normal furnace cooling offers little advantage over air cooling for the heavily cold worked material.

Aging of a pilot specimen which duplicates the cross section of the commercial part at a selected temperature for shorter periods, followed by air cooling or furnace cooling, is recommended as a guide for an economical commercial method adequate for intended use.

Where creep strength or stress-rupture properties of Inconel "X" are critical, the maximum time at temperature is recommended.

(e) Springs, wire or strip, cold worked approximately 15% (No. 1 temper) for use in the range of 800 to 1100° F., are hardened by heating at 1350° F. for 16 hr. and air or furnace cooling.

After aging, the springs should be preloaded 10% above the maximum working stress and held for 1 hr. at a temperature 100° F. above the maximum operating temperature. Figure 4 gives the general relationships between hardness and heat treatment of hot rolled Inconel "X", and the strengthening possible by cold work and aging.

Stress Equalizing

Suggested stress equalization for "K" Monel, "KR" Monel, Duranickel and Permanickel is to heat 1 to 2 hr. at 575 to 650° F. Recommended temperature is 650 to 900° F. for Inconel "X" when it will be used up to 650° F., and 100° F. above the maximum operating temperature when it will be used at higher service temperatures. The time may vary between 1 and 2 hr., depending upon the thickness of the material. Stress equalizing after age hardening is unnecessary, since aging accomplishes it adequately. Coil springs, wire forms, and flat spring stampings usually need such treatment. If coil springs are to be given a cold "set", or cold pressed after coiling, stress equalization should be carried out *prior* to the setting operation; this involves stressing the material beyond the elastic limit. Any internal cold working stresses set up by this operation are in such a direction that they will improve the material. If stress equalized after cold pressing, part of the cold work will be removed by the treatment.

Table V — Short Aging Treatments for Inconel "X" Sheet

Cold rolled to 0.065 in., annealed 20 min. at 2000° F. and air cooled

Aging		Tensile				C-Scale Hardness
Temp.	Hr.	1% Offset	0.2% Offset	Ultimate	Elon. in 2 In.	
0	0	31	45	111	47	8
1300	1	85	95	155	35	27
1300	2	90	107	165	28	31
1300	4	96	115	172	26	33
1300	8	100	120	173	24	34
1300	20	106	122	176	23	35
1350	1	92	104	163	29	30
1350	2	97	111	169	26	32
1350	4	98	116	172	25	33
1350	8	102	120	174	23	34
1400	1	96	109	167	29	32
1400	2	98	113	170	24	33
1400	4	99	115	171	23	33
1450	1	90	106	165	29	31
1450	2	98	111	166	28	31
1500	1	87	104	161	27	29
1500	2	92	105	166	29	31
1600	1	71	83	140	32	22

In highly stressed parts, such as pump shafts operating at high peripheral speeds, it is often necessary to use precisely straightened rods having tolerances closer than commercial. Should it be necessary to straighten age hardened material by hand, it should be stress equalized, holding at 575° F. for 3 hr.

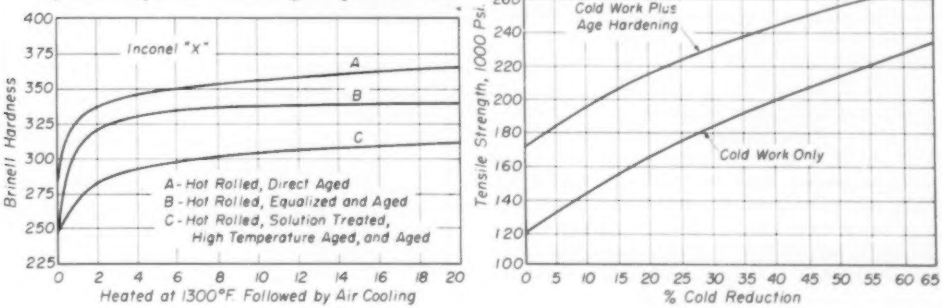
Heat Treating Equipment

Vacuum Furnaces for Bright Hardening — Hardening in vacuum is the only procedure which will give a perfectly bright surface. Commercially this is possible with small parts only; consequently the semibright must be accepted as a standard surface, and suitable clean-up must remove the slight tarnish.

Batch-Type Furnaces for Semibright Hardening — The use of sealed furnaces and controlled atmospheres will not result in an absolutely bright surface. Material so treated will have a very thin, superficial, but tenacious oxide coating (which may be removed readily by tumbling, vapor blasting, mechanical polishing or pickling).

Furnaces for Open Hardening — Open hardening, or hardening of parts in a furnace into which no artificial atmosphere such as hydrogen

Fig. 4 — Age Hardening of Inconel "X" as Influenced by Time and Degree of Cold Work



is to be introduced, may be done best by using electric, radiant tube, air recirculating furnaces, or full, muffle-type furnaces. They should be sealed after loading to prevent infiltration of air and consequent oxidation of the work. Furnaces in which the burner fires directly into the chamber are not recommended due to difficulty of control within the fairly close limits desired.

Parts that are to be rough machined, finish machined, ground to size, or where the surface appearance is not of major importance, are commonly hardened in this manner.

Salt Baths are used for special work with small parts. Particular care must be exercised initially to remove all traces of sulphur from the fused salts, otherwise the work will be embrittled. This may be accomplished in 2 to 3 hr. by adding a small amount of powdered borax and charcoal (3 to 1 mixture) to the fused salts. If small test pieces of nickel or Monel strip or wire are not embrittled after 3 or 4 hr. in the purified salt bath, the desulphurizing treatment has been sufficient.

After heating, the work is quenched in water to free it from salt. The annealed or hardened material will not be bright and must be pickled.

Atmospheres for Semibright Hardening — Suitable atmospheres include hydrogen, cracked ammonia, nitrogen, cracked and sulphur-free natural or city gas, cracked hydrocarbons, or a generated atmosphere containing some combination of carbon monoxide, hydrogen, nitrogen and hydrocarbons. Propane or butane should be avoided unless the formation of soot can be prevented or easily removed.

A useful procedure, when reducing gases are not available, is to harden the work in clean iron filings or chips, which are not contaminated by sulphur or low-melting metals and alloys such as lead and babbitt, and clean the work finally by tumbling, vapor blasting or pickling.

Protection From Contamination by Foreign Material — It is important that material be both clean and dry before hardening. Parts to be heat treated should first be degreased thoroughly, preferably by readily vaporized solvents, such as trichlorethylene. Alkaline cleaning solutions can be used if the metal is dipped later in very hot water to remove traces of the cleaner.

Even when semibright hardening is not required, it is very necessary to remove coatings of oil or grease. Some lubricants contain appreciable amounts of sulphur which, if not removed, may cause some damage to the material. Even though sulphur might not be present, the lubricant would form a hard coating on the metal and produce a very objectionable appearance.

Nominating Committee

IN ACCORDANCE with the constitution of the American Society for Metals, President WALTER E. JOMINY has selected a nominating committee for the nomination of president (for one year), vice-president (for one year), and two trustees (for two years each). This committee was selected by President JOMINY from the list of candidates submitted by the chapters. The personnel is:

KARL L. FETTERS (Mahoning Valley Chapter), *Chairman;* Special Metallurgical Engineer, Youngstown Sheet & Tube Co., Youngstown, Ohio.

GEORGE M. ENOS (Purdue Chapter), Chemical and Metallurgical Engineering Bldg., Purdue University, Lafayette, Ind.

M. L. FREY (Milwaukee Chapter), Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.

F. T. MCGUIRE (Tri-City Chapter), Deere & Co., Materials Engineering Dept., Moline, Ill.

J. C. NEEMES, JR. (North West Chapter), International Nickel Co., Northwestern Bank Bldg., Minneapolis 2, Minn.

S. R. PRANCE (Dayton Chapter), Inland Mfg. Division, General Motors Corp., 2727 Inland Ave., Dayton 1, Ohio.

R. B. SCHENCK (Saginaw Valley Chapter), Chief Metallurgical Engineer, Buick Motor Division, Flint 2, Mich.

L. P. TARASOV (Worcester Chapter), Norton Co., Research and Development Dept., Worcester 6, Mass.

F. M. WALTERS (Los Alamos Chapter), P. O. Box 1663, Los Alamos, N. M.

THIS committee will meet during the third full week in the month of May. It will welcome suggestions for candidates in accordance with the Constitution, Article IX, Section 1 (b), which provides that endorsements of a local executive committee shall be confined to members of its local chapter, but any individual member of a chapter may suggest to the nominating committee any candidates he would like to have in office. Endorsements may be sent in writing to either chairman or any member of the committee.

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Company, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario.

Extra-Low-Carbon STAINLESS STEEL

New Type Chromium-Nickel Steels Have Added Corrosion Resistance

New and improved austenitic stainless steels of the 18-8 type have been developed which have superior corrosion resistance after being exposed to heat. These steels, known as extra-low-carbon stainless steels, were designed especially for use in welded and stress-relieved equipment that is exposed to more severe corrosive conditions than are normally encountered by other types of straight 18-8 stainless steel.

Under severe corrosive conditions, intergranular attack may occur in some of the higher carbon grades of austenitic stainless steels that have been subjected to the temperature range of 800 to 1600 deg. F. during welding or hot forming operations. It is generally agreed that this type of corrosion is caused by complex carbides that are formed at the grain boundaries of the stainless steel during heating.

The effect of heat is rarely harmful in the ordinary fabrication of stainless steel for most applications, such as in architecture, the food and dairy industries, in hospitals, and in the home. However, in the chemical and other allied industries, where stainless steel is used in the handling of very corrosive chemicals, these new extra-low-carbon stainless steels should most certainly find wide use.

Fig. 1 Left: Carbide precipitation at the grain boundaries of an 18-8 stainless steel, containing 0.059 per cent carbon, after being held at 1200 deg. F. for 1 hour. Right: Absence of carbide precipitation in 18-8 stainless steel of 0.03 maximum carbon content, after being held at 1200 deg. F. for the same length of time.

In general, there are three ways in which the precipitation of carbides can be controlled in stainless steel:

1. Heat-treating so that the carbides present are dissolved.
2. Alloying with an element, such as columbium, tantalum, or titanium, that will tie up the carbon in the form of a harmless carbide.
3. Decreasing the carbon content of the steel.

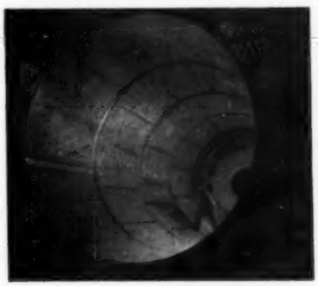


Fig. 2. The new extra-low-carbon stainless steels are especially suited for large types of process equipment, such as this fractionating tower. They require no heat-treatment after welding.

Heat-Treatment After Welding

Before the development of extra-low-carbon stainless steel, or of the "stabilized grades," one means for preventing intergranular corrosion was to heat-treat stainless steel that had been subjected to the dangerous temperature range, so that the precipitated chromium-carbides would go back into solid solution. It was found that when a welded part was heated to temperatures of 1950 to 2000 deg. F., and then cooled rapidly, most of the carbides were retained in solid solution. This extra heat-treatment is sometimes impractical, however, because of the design or massive size of some types of welded equipment.

Decreasing Carbon Content

A recent development in preventing intergranular corrosion has been the extra-low-carbon stainless steels. To be substantially harmless in stainless steel for as-welded or welded and stress relieved chemical equipment operating at temperatures under 700 deg. F., carbon must not be present in quantities over 0.03 per cent.

In 1937, ferrochrome with 0.03 per cent maximum carbon was first produced for the steel industry by ELECTROMET. This product has helped make it possible to produce very-low-carbon stainless steels—steels that are completely immune to intergranular corrosion after welding or after subjection to a stress-relieving heat-treatment.

The amount of stabilizing element that is necessary to "fix" carbon in stainless steel is in direct proportion to the carbon content of the steel. Therefore, the lower the carbon the less is the amount of stabilizing element required. Lowering the carbon content is an efficient means of conserving columbium, tantalum, and titanium.

Metallurgical Service Available

If you use welded stainless steel equipment, it will pay you to investigate the advantages of using extra-low-carbon steels. If you produce stainless steel, our metallurgists will be glad to give you technical assistance in the use of ferrochrome of 0.03 per cent maximum carbon. For further information, write to the nearest ELECTROMET office.

For a more detailed account of the properties of extra-low-carbon stainless steel, write for a free copy of the technical paper, "Resistance to Sensitization of Austenitic Chromium-Nickel Steels of 0.03% Max. Carbon Content".

Personal Mention

Robert I. Jaffee

Robert I. Jaffee ⊕, who is well known in the metallurgical field for his work on the technology of the refractory metals, the lower-melting rare metals, and the precious metals, has recently been named supervisor of research in nonferrous physical metallurgy at Battelle Memorial Institute, Columbus, Ohio. Dr. Jaffee is the author of many technical papers, articles and patents in his field of specialization. In 1949 he was named by the Ohio Junior Chamber of Commerce as one of the five outstanding young men of Ohio on the basis of his contributions to titanium research. He holds degrees in chemical engineering and metallurgy from the Illinois Institute of Technology, Harvard University, and the University of Maryland. Although associated with Battelle since 1943, he was formerly with Leeds and Northrup Co. and the University of California. Dr. Jaffee is a member of the American Institute of Mining and Metallurgical Engineers.

William M. O'Donnell ⊕ has been appointed to the executive staff for sales and metallurgical development at American Metallurgical Products Co., Pittsburgh.

Frederick J. Griffiths ⊕ has been elected to the board of directors of Follansbee Steel Corp., Pittsburgh.

John Mikulak ⊕ has been appointed assistant to the vice-president in charge of manufacturing at the Worthington Pump and Machinery Corp., Harrison, N. J.

The following promotions have been announced by the Colorado Fuel and Iron Corp., Pueblo, Colo.: **Rudolph Smith** ⊕, works manager; **Iver T. Ellingboe** ⊕, assistant superintendent of the openhearth; **Harold Gumma** ⊕, assistant superintendent of the rolling mills; and **Victor Johnson** ⊕, rolling mill superintendent.

Paul L. Asnis ⊕, formerly with Lucius Pitkin Inc., New York, is now employed as a metallurgist for Wilbur B. Driver Co., Newark, N. J.

Robert W. Ryan ⊕ has left Cleveland Graphite Bronze Co., Cleveland, to become assistant superintendent of the aluminum foundry, Sonken-Galamba Corp., Kansas City, Kan.

David I. Sinizer ⊕ has been appointed technical industrial liaison officer at Massachusetts Institute of Technology, Cambridge, Mass. In his new post, Dr. Sinizer will assist in liaison with industrial firms contributing through general grants-in-aid to strengthen M.I.T.'s program of research and education.

William E. Mahin

William E. Mahin ⊕ has recently been named director of the metallurgical projects division of the new Metallurgical Advisory Board of the National Research Council. He will divide his time between research administration of the Armour Research Foundation of Illinois Institute of Technology, Chicago, where he is director of research, and his new position in Washington, D. C. Mr. Mahin, who graduated from the University of Notre Dame in 1928 and received his M.S. degree from Carnegie Institute of Technology in 1933, was formerly connected with the Vanadium Corp. of America, in charge of metallurgical research, and the Inland Steel Co., as a metallurgist. He spent ten years at Westinghouse Electric Corp., Pittsburgh, as head of metallurgical engineering. He was named director of research at the Foundation in 1949, after three years' service as chairman of the metals research department there. Mr. Mahin is chairman of the Chicago Chapter ⊕ and a member of the Society's national publications committee, a member of the executive committee of the Chicago section of the American Institute of Mining and Metallurgical Engineers, and a member of the American Society for Testing Materials, the Institute of Metals, the British Iron and Steel Institute, and the American Foundrymen's Society.

Frederick A. Locke ⊕ has been appointed assistant general superintendent of Braeburn Alloy Steel Corp., Braeburn, Pa.

Typical thermometer and barometer desk set made by Standard Thermometer, Inc., 952 Dorchester Ave., Boston 25, Mass. Standard's instruments are not only sold to government, industry and over the counter, but many are also imprinted with company names and become valued gifts to top executives of important customers.

Punching spoke holes in brass cups which have been drawn, cut, and passed by Inspection.

TO MEASURE TIME AND WEATHER

BEGIN WITH THE BRASS

● Standard Thermometer, Inc., is a well-known maker of thermometers, barometers, hygrometers, and clocks, for outdoor, desk, and industrial use. Naturally, brass is an important item in these instruments, being used for cases because of its golden beauty and for operating parts because of its reliable physical characteristics, including corrosion resistance.

Fabrication methods include stamping and drawing of cases and bezels. The company is an old and experienced one, dating back to 1885, and has been a Revere customer since that time. Recently it began to experience certain fabrication difficulties. When Revere heard about them, the Technical Advisory Service was asked to look into the matter. The brass being used was analyzed, and factory tools and methods studied. An elaborate 17-page report was prepared, including photographs of micro-sections to show the grain structure of various samples, and detailed recommendations were made. In general, it was found that such things as puckers, orange peel, and flare were due to a combination of factors, including composition of the brass, its temper, the dies, and the lubricant used on them. Standards were set up for metal specification and though Revere does not design dies, suggestions were made for the consideration of the designers.

After digesting the report and putting the recommendations to the proof, Standard wrote: "We are extremely grateful for this information, and it represents a splendid job and one of great value to us."

Perhaps Revere can work with you too on such matters as specification, fabrication, ideas to save precious metal. Our collaboration is freely given.

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Personals

S. Frederick Magis ⊕, formerly consultant on production of steel and finished steel products at Siderurgica Venezolana "Sivensa" S. A., Caracas, Venezuela, has been elected general manager of the company.

K. R. Togstad ⊕ has been appointed manager of the Milwaukee plant of Central Steel and Wire Co.

Walter C. Keil ⊕ has been appointed assistant superintendent in charge of smelting operations at the American Smelting and Refining Co., Federated Metals Div., Newark, N. J.

H. C. Morgan ⊕, is employed as general manager of the electric section of the Commonwealth Industrial Gases Ltd., North Carlton, Victoria, Australia.

Arthur L. Ludwig ⊕, is now spectrographer at Trico Products, Buffalo, N. Y.

Lyman Y. Burch ⊕ is on military leave from Chevrolet-Flint Manufacturing and is serving with New Jersey State Headquarters Selective Service System in an administrative capacity.

Philip C. Pfister ⊕ is now an instructor in mechanical engineering at West Virginia University. He previously held a similar position at City College of New York.

Borg-Warner Corp., Chicago, has appointed **Maurice Nelles** ⊕ director of the engineering development section.

Paul A. Duke ⊕, formerly Atlanta representative for the warehouse division, has been named product engineer by the Atlanta Steel Co., Atlanta, Ga.

Dominic A. Verive ⊕ has been employed as a research engineer with the Continental Can Co., Chicago, since his graduation from Missouri School of Mines & Metallurgy in June.

Zay Jeffries ⊕ has been elected an honorary member of the American Society of Mechanical Engineers recently.

Alexander Mitinsky ⊕ is now an engineer with Super Chrome Engineering Co., Los Angeles.

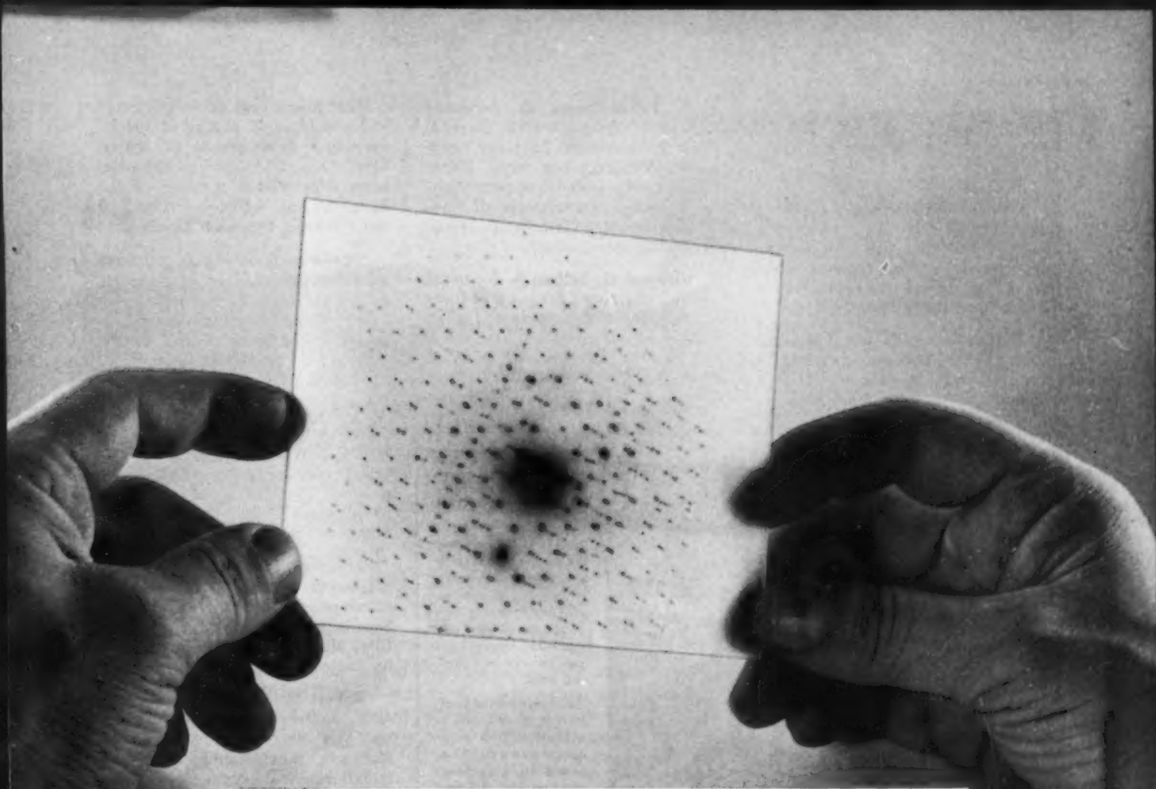
Robert C. Kuhn ⊕ has been appointed assistant district manager in the Cleveland sales office of the Crucible Steel Co. of America.

J. M. Zvon ⊕, formerly with Atlantic Wire Co. and Driscoll Wire Co., has accepted a position as general foreman in charge of the wire mill at Gilbert and Bennett, Georgetown, Conn.

Ross M. Burthwick ⊕, publicity chairman and member of the executive committee of the Columbus section, American Welding Society, is leaving the United States to become a lieutenant on special naval duty with the Canadian Navy.

Paul G. Bastien ⊕, scientific director of Schneider & Co., France, has been elected a president of the Société des Ingénieurs Soudeurs, and president of the applied physics section of the Société des Ingénieurs Civils de France.

The Penn State Chapter ⊕ has selected **J. L. Mauthe,** president of Youngstown Sheet and Tube Co., as the 1951 recipient of the David Ford McFarland Award for Achievement in Metallurgy.



Personals

Charles L. Carlson has joined the metallurgical application section of the materials engineering department of Westinghouse Electric Corp., East Pittsburgh, Pa., as a metallurgical engineer.

E. O. Dixon has been appointed vice-president in charge of research and metallurgy at the Ladish Co., Cudahy, Wis.

A. L. Simmons, formerly with the Commonwealth Government Ammunition Factory, Footscray, Victoria, has been transferred to the Defense Supply Planning Branch, Department of Supply, Melbourne, Victoria, Australia, as senior metallurgist.

Howard E. Pellett, formerly sales engineer for American Machine and Metals, Inc., in the California territory, is now serving in a similar capacity with the Lindberg Steel Treating Co., Los Angeles.

L. F. Reinartz, recently elected vice-president in charge of special operating development of Armco Steel Corp., Middletown, Ohio, has been appointed a member of the Metallurgical Advisory Board of the National Research Council.

Theodore E. Burke, formerly with Vanadium Corp of America, as sales engineer, has joined the Great Lakes Carbon Corp., St. Louis, where he is engaged in the selling of byproduct coke and chemicals.

Andrew B. Smith, formerly principal surveyor for the Great Lakes, American Bureau of Shipping, resigned to accept the position of superintendent of vessel properties with the Interlake Steamship Co., Cleveland.

The appointment of **Howard N. Simms** as director of welding development and control of Black, Sivalls and Bryson, Inc., Kansas City, Mo., was announced recently by the company.

Robert T. Sinnott, formerly sales engineer for Armco Drainage and Metal Products, Topeka, Kan., is now employed in the metallurgical department of Lindberg Steel Treating Co., Chicago.

Raymond H. Sholtz, formerly metallurgical engineer at the Fansteel Metallurgical Corp., North Chicago, Ill., has recently been appointed senior metallurgist and head of the metallurgical division of the laboratory at Rock Island Arsenal, Rock Island, Ill.

Harold M. Cobb has left the Westinghouse Aviation Gas Turbine Co., to accept a position as supervisory metallurgist at the Wright Aeronautical Corp., Wood-Ridge, N. J.

John F. Thompson, president of the International Nickel Co. of Canada, Ltd., has been elected to the additional office of chairman of the board of directors. **Paul D. Merica**, executive vice-president and a director, has been elected a member of both the executive committee and the advisory committee of the company.

Robert Krogh is now in charge of sales in the Cincinnati area for Ipsen Industries, Inc., Rockford, Ill.

Donald E. Feather has taken a position as metallurgist with the Wisconsin-Appleton Co., South Milwaukee, Wis.

Pressure-Welded Copper Alloys*

BECAUSE pressure welding eliminates the melting of the parent metal or of a filler rod or electrode, there is no cast metal in the joint. Therefore, the possible complications attendant with the use of fusion welding — such as the formation of pores on solidification, the formation of shrinkage cavities, shrinkage cracks, the trapping of slag inclusions, and inadequate fusion of the parent metal — cannot arise in pressure-made welds.

The pressure welding characteristics of deoxidized copper and nine commercial copper-base alloys were determined by making butt welds with $\frac{1}{2}$ and $\frac{5}{8}$-in. diameter rod, the efficiency of jointing being assessed by tensile testing and microexamination. The welded joints made with each alloy were of a strength equal to the inherent strength of the annealed material. Welding took place by recrystallization across the interface.

Taking as the criterion of weldability the minimum deformation required to produce maximum joint strength, the work of the authors shows the order of merit of the metals tested to be: Deoxidized copper, 70-30 and 80-20 cupronickel, 93-7 and 91-9 phosphor bronze, 85-15 brass, silicon bronze, and aluminum bronze.

The test bars were $2\frac{1}{4}$-in. long × $\frac{3}{4}$-in. diameter rods that were machined down for a length of about $\frac{1}{2}$ in. to a $\frac{1}{2}$ or a $\frac{5}{8}$-in. diameter. The rods were placed in a cylindrical hole machined in the center of steel blocks bolted to the two platens of the press. Heating was effected by means of an oxy-acetylene ring burner so arranged as to keep the jets directed upon the line of the interface. A neutral flame was employed to inhibit oxidation and to prevent carbon deposition. Temperatures of 300 to 1000° C. (temperature at which the pressure was applied was taken as the temperature at the interface) and pressures of 500 to 15,800 psi. were used in the investigations.

It was learned that joint strength

(Continued on p. 546)

*Abstract from "The Pressure-Welding Characteristics of Some Copper-Base Alloys", by Edwin Davis and Eric Holmes, *Journal of the Institute of Metals*, Vol. 77, 1950, p. 185 to 206.


WHEREVER METAL TAKES A BEATING
. . . in manufacturing, in service, or both—
no other alloys possess the combination of properties of Phosphor Bronze. And *nowhere* is finer Phosphor Bronze produced than in the mills of The American Brass Company—in sheet, wire, rod and tube.
Illustrated here are a few of the myriad of bellows and bellows devices made of Anaconda Phosphor Bronze and other Copper Alloys by The Bridgeport Thermostat Division of Robertshaw Fulton Controls Co., Bridgeport, Conn.
ANACONDA
PHOSPHOR BRONZE
HIGH
Tensile strength
Elastic limit
Resistance to fatigue
Resistance to corrosion
Resistance to wear

Pressure-Welded Copper Alloys

(Continued from p. 544)
was influenced by the surface condition before welding, mechanical preparation proving most suitable, and by the deformation taking place during welding. With the exception of deoxidized copper, surfaces to be butt welded were prepared by cleaning the face with No. 0 emery paper while the test bar was rotated in a lathe, and afterward washed in acetone.

Formation of pressure welded joints in deoxidized copper was adversely affected by emery particles that were not removed by washing. In place of this technique the copper face was etched with nitric acid and then washed with water and dried in alcohol. It was found that welding time, pressure, and temperature were of importance only in so far as they affected deformation, providing the welding temperature exceeded the recrystallization temperature of the material.

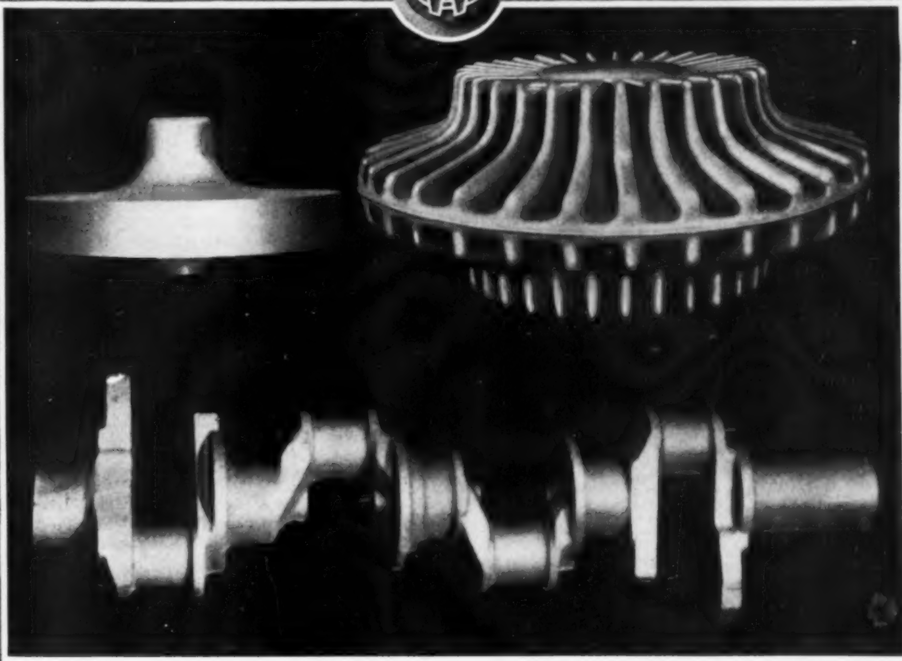
H. J. Roast

Room Temperature Creep and Relaxation*

In 1934 Davidenkov and Sakharov first pointed out the possibility of creep and relaxation in steels at room temperature from studies made of the elastic after-effect in steel wires. Later, Krisch studied room temperature creep in five steels and found that in 0.13 and 0.23% carbon steels creep ceased after 5 and 100 hr., respectively, but did not stop even after 400 hr. in alloy steels. Creep was observed in most instances only when the stress exceeded the yield point.

The data on relaxation at room temperature were obtained from 18-8 stainless steel that had been water quenched from 1920° F. and on low-carbon iron normalized at 1740° F. Relaxation tests for times up to 1600 hr. were carried out on ring specimens. It was found that the low-carbon iron did not show relaxation at the stresses employed; stainless steel showed especially pronounced relaxation *(To p. 548)*

*Abstract from "Relaxation of Austenitic Steel at Room Temperature", by I. A. Oding and E. N. Volosatova, *Doklady Akademii Nauk SSSR*, Vol. 71, 1950, p. 659 to 662.



Room Temperature Creep and Relaxation

(Continued from p. 546) at higher initial stresses and during the initial period of the test. Five other types of austenitic stainless steel were tested and they also exhibited significant relaxation.

Relaxation is the result of diffusion plasticity that occurs at grain boundaries and stops when the grains block one another. On successive restressing it would be expected that the amount of relaxation would constantly decrease. An 18-8 specimen subjected to initial stresses of 60,000 psi. showed that almost no relaxation occurred after the sixth restressing.

Relaxation also affects the value of the modulus of elasticity determined from stress-strain relations. On stressing 18-8 for the first time in a Martens-Kennedy tensometer, a modulus of 23,500,000 psi. was obtained. Restressing this specimen increased the value to 25,700,000 psi., and on the sixth stressing a value of 27,400,000 psi. was obtained. The low-carbon iron showed a constant modulus on successive restressing.

A. G. Guy

ZrC·Cb Cermals*

An investigation was made of the sintering process and the sintering mechanism of a zirconium carbide – columbium cermal (12.5% by weight of columbium). The specimens used were prepared by hot-pressing and the effects of sintering temperature and time at temperature on the structures were determined. A bonding study was also made of a hot-pressed zirconium carbide specimen and columbium powder. Lattice-parameter measurements by X-ray diffraction, microstructure studies, density measurements, and room-temperature modulus-of-rupture evaluations were used to establish the sintering conditions and to investigate the sintering mechanism.

The results of the investigation indicated that the sintering mechanism is one in which columbium

(Continued on p. 550)

*Abstract of "Sintering Mechanism Between Zirconium Carbide and Columbium", by H. J. Hamjian and W. G. Lidman, Technical Note 2198, National Advisory Committee for Aeronautics.

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Technical Topics

MAGNETISM IN AUSTENITIC STAINLESS STEEL

Norman S. Mott
Chief Chemist and Metallurgist

In the normal specification range for the 18-8 chromium-nickel stainless steels, especially when the carbon is low, ferrite and the resultant magnetism will often be found. It must not be construed, however, that this condition is detrimental to the properties of stainless steel; in fact, in many cases it is highly desirable.

The fully austenitic stainless steels, when heated in the carbide precipitation range (900-1600° F.) have their carbon precipitated as chromium carbide along the grain boundaries. This depletes the boundaries of chromium with the result that the alloy becomes susceptible to intergranular corrosion.

When alloys containing amounts of ferrite from 5-15% are heated in this temperature range, it is found that the carbides tend to form predominantly in the ferrite areas. Since these areas are disconnected and well distributed, the condition does not promote intergranular corrosion.

Stainless steels with free ferrite up to 30% in amount retain good mechanical properties, although they show a slight decrease in ductility and toughness. Their strength and hardness are increased.

Estimation of the presence and approximate amount of ferrite may be accomplished by the use of a phase diagram based upon nickel and chromium equivalent values.* The nickel and chromium equivalent values are computed by the equations:

$$Ni^e = Ni\% + 0.5\,Mn\% + 30\,C\%$$

$$Cr^e = Cr\% + Mo\% + 1.5\,Si\% + 0.5\,Cb\%$$

The boundary line between fully austenitic alloys and those which contain ferrite is expressed by the equation:

$$Ni^e = \frac{(Cr^e - 16)^2}{12} + 12$$

When a higher percentage of nickel is specified in type 316 moly bearing alloys in order to make them completely austenitic in structure, they become susceptible to intergranular corrosion, and if they are to be heated in the carbide precipitation range, as would occur during welding, additions of columbium are required to counteract this susceptibility.

Molybdenum additions to 18-8 stainless make the alloy magnetic due to the formation of ferrite, and existing data have shown that the presence of this ferrite does not interfere with the high corrosion resistance of the alloy. In this form, it enjoys a wide range of usage where excellent resistance to corrosive media and the effects of welding heat are required.

*A. L. Schaeffler, Metal Progress, November, 1949, p. 680-B.

ZrC·Cb Cermals

(Continued from p. 548)

atoms diffuse into the zirconium carbide lattice, displace zirconium atoms, and form columbium carbide and zirconium metal. This columbium carbide is completely soluble in the matrix of zirconium carbide and a homogeneous solid solution of carbides is formed. At the sintering temperature of 3900° F., zirconium metal forms in the grain corners of the carbide structure.

Size and distribution of the metal phase could be controlled by two sintering variables, temperature and time at temperature. The specimen with a fine dispersion of metal has the highest strength.

Unconventional Methods in Powder Metallurgy*

ORDINARY powder metallurgy (compacting and sintering) cannot produce long shapes because the pressure does not spread uniformly and the powder far from the piston is not compacted enough. Even the use of a double-piston mold does not help much. A simple method for obtaining greater lengths consists of pressure welding smaller lengths at a temperature above 1800° F. The joints must be painted with a thin layer of water-wetted finely powdered iron, and the pressure used does not have to exceed 2.2 psi. (The author says 13 g. per sq.cm. but this is an error due to improper division of the load used by the area of the joint.) The weld is very good and no trace of the joined surfaces can be found on machining.

Obviously of greater importance is his method for preparing long rods and tubes by ramming the metallic powders into a tubular container of a suitable metal, plugging up the ends and drawing the sheathed powders through a die or sending them through grooved rolls, which can be done either hot or cold. Not much reduction is necessary. An iron sheath filled with 80% Fe and 20% Al or 88% Fe, 10% Pb and 2% graphite was drawn through a die in two steps, from 0.929 to 0.866 in. outside diameter. *(Continued on p. 552)*

***Abstract from "Some New Methods of Powder Metallurgy", by G. Wassermann, *Metallforschung*, Vol. 2, 1947, p. 129-137.**

Unconventional Methods in Powder Metallurgy

(Continued from p. 550)

The extrusion of sintered billets through a die is a well-known process, but the author obtained good results by die-sinking cakes of sintered iron without any previous compacting. The amount of powder needed was brought to the proper temperature inside an iron crucible with walls protected by a layer of graphite, and the self-sintered cake was dropped into the mold and subjected to two strokes of the press. A rather homogeneous cup-shaped object was removed from the die. Its porosity was only 1 to 4%, and test bars made out of the walls and the bottom have shown (after annealing) 50,000 to 60,000 psi. tensile strength with 26 to 36% elongation. Brinell hardness measured with a 2.5-mm. ball under 62.5-kg. load was none too consistent, ranging from 141 to 190, as pressed, and 122 to 140, as annealed. Two sizes of cup were experimented with, one weighing 1.43 lb., the second 2.75 lb. The wall thicknesses were quite different, but the mechanical properties closely similar. Impact test bars (0.157 x 0.157 x 1.77 in. unnotched) gave high figures, showing that the shock sensitivity — the weakest feature of most powder metal compacts — was absent.

M. G. CORSON

SiO in Acid Steel*

INVESTIGATION of the behavior of SiO_2 at high temperatures in a reducing medium leads the authors to the conclusion that SiO is an intermediate reaction product and that its formation accounts for the copious fume production in the melting of ferrosilicon and other silicon alloys. Although SiO may form during the melting of acid steel, the authors claim such formation can occur only under reducing conditions such as those existing during the diffusion deoxidation of electric steel under acid slags. Characteristic of the latter is deoxidation using high silica (60 to 65% SiO_2), well-deoxidized slags

(Continued on p. 554)

*Abstract from "Silicon Monoxide in the Melting of Acid Steel", by P. V. Gel'd, A. I. Kholodov and N. M. Buinov, *Doklady Akademii Nauk SSSR*, Vol. 70, 1950, p. 679 to 682.

SiO in Acid Steel

(Continued from p. 552)

(3% FeO, 7% MnO) containing 20 to 25% CaO. Under the action of a reducing agent such as coke dust, the silica is reduced and the resulting silicon is transferred to the metal. The conditions during this period are said to be similar to those existing in the melting of silicon alloys.

In order to make a more detailed study of SiO in steel melting furnaces, a number of four-ton melts of carbon steel were made in an acid electric arc furnace. During the course of deoxidation of a given heat the slag composition changed due to the attack of the lining, and the SiO_2 content increased from 63 to 82%. The slag thickened and a considerable amount of dull blue sublimate flakes, some as large as 6.3 x 2.8 x 1.4 in., were emitted from the furnace. These had a specific gravity of 0.02 to 0.05, and were quite elastic in compression. Analysis of the flakes gave the following composition: 70.16% SiO_2, 2.09% CaO, 0.77% MgO, 41.07% Fe_2O_3, 3.34% MnO, 0.18% S; Al_2O_3 was not detected. Total of these constituents is 117.61% and even when the existence of iron as metallic iron is taken into consideration, the total exceeds 100%. This situation, the authors state, can be explained only by the presence of SiO. It was noted that when the sublimate fell to the floor it glowed, presumably because of the burning of SiO. During the deoxidation period, the slag analysis also totaled more than 100%.

Microscopic examination at 600 × revealed the sublimate as an aggregate of brownish spheres less than 0.00004 in. in diameter. With the aid of the index of refraction, n = 1.485, the material was identified as crystobalite. Electron micrographs at 21,000 × showed that flakes of sublimate contained larger spherical particles than did fume specimens. Fume samples collected during the melting of 75% ferrosilicon had a microscopic appearance and index of refraction similar to the carbon steel fume samples. This was considered as additional evidence of the similarity of conditions in the two melting processes and of the presence of SiO as an intermediate material in both instances.

During the course of the refining period the size of the spheres observed in electron micrographs of fume samples decreased from a

(Continued on p. 556)

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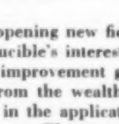

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SiO in Acid Steel

(Continued from p. 554)
maximum of 1μ to about 0.1μ. This behavior corresponded to exhaustion of the reducing agent and a decrease of SiO in the gas phase.

Because of the presence of SiO in the gas phase, and the peculiarity that the total slag analyses were over 100%, the authors conclude that SiO also exists in the liquid slag and metal. The work of Zapffe and Sims is cited as support for their conclusion regarding the presence of SiO in the metal.

A. G. Guy

Metal-to-Glass Seal*

SOME years ago, a nickel-chromium-iron alloy (42% Ni, 6% Cr) was developed in America for exact matching to ordinary soft-lead glass such as used in the manufacture of electrical lamps and valves. The wire normally used is a copper-clad nickel-iron alloy, but there are occasions when it is advantageous to use a homogeneous alloy wire. While it is true that the American alloy provides seals with substantially zero stress at room temperature, photo-elastic measurements show that it does not form a perfect match to lead glass at all temperatures as indicated by stress-temperature curves. The stress developed in a seal which cools from the annealing temperature increases to a peak at about 580° F. before decreasing to a very low value at room temperature.

The problem, therefore, was to find a new alloy matching lead glass more satisfactorily over the whole temperature range. The degree of match achieved should be at least as satisfactory as that obtained with the "Kovar" type iron-nickel-cobalt alloys to boro-silicate glass. It is often considered that the virtue of the iron-nickel-cobalt alloy lies in the fact that the Curie temperature of the alloy and the transformation temperature of the glass are about the same, with approximately equal coefficients for glass and metal below and above this temperature. These, however, are not essential conditions for a good glass-to-metal match. All that is necessary is that

(Continued on p. 558)

*Abstracted from "A Nickel-Chromium-Iron Alloy for Sealing to Glass", by J. E. Stanworth, *Journal of Scientific Instruments*, October 1950, p. 282 to 284.

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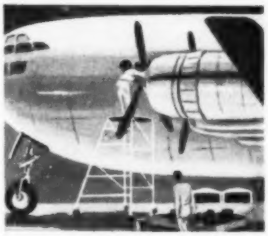

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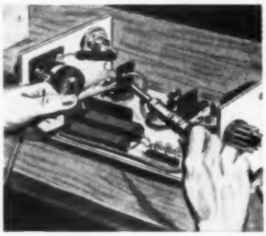

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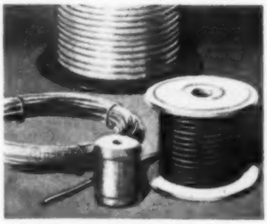

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Metal-to-Glass Seal

(Continued from p. 556)

the Curie and transformation temperatures and the expansion coefficients should be so related as to ensure sufficiently low stress at any temperature. For example, an excellent match between a glass and metal is possible, even with a difference of 150° between the Curie and transformation temperatures.

Preliminary consideration indicated that it would be preferable to have alloys with higher nickel content than the American alloy. The alloys were melted in small billets weighing approximately 50 g. Raw material used was carbonyl nickel powder; iron powder (containing 0.02% C, 0.13% Mn and 0.03% Si); and chromium-nickel powder (containing 73.7% Ni, 22.3% Cr, 0.2% Si, 0.4% MnO, 0.2% C, 1.0% Fe). Melts were made in small beryllium oxide crucibles at 2800° F. in an atmosphere of very dry hydrogen.

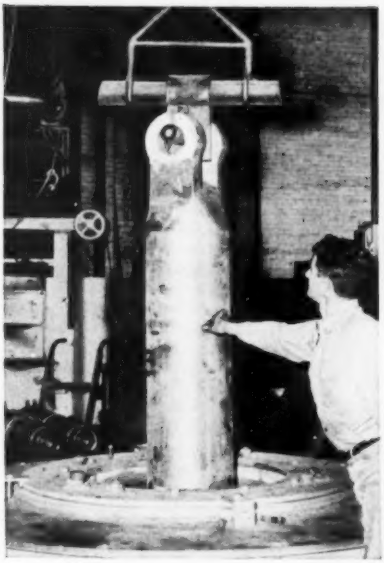
Each melt was held 15 to 20 min. after reaching 2700 to 2800° F., and was then quenched in hydrogen at room temperature. Suitable small sections of the billet were cut, cold rolled to a thickness of 0.020 in., and the small samples of sheet thus obtained were suitably prepared for glass sealing by degreasing, etching, and firing in wet hydrogen under carefully controlled conditions to produce the required oxide surface.

Each sheet-metal sample was then sealed to standard lead glass and a sandwich seal was prepared for photo-elastic observation. The interface of the seals was olive green in color, and the adhesion of glass to metal, as determined by crushing in a vice, or by impact with a hammer, was very satisfactory. Stress-temperature curves were determined at a cooling rate of 8° F. per min. for each seal.

The nominal nickel and chromium contents of the nine alloys tested, as calculated from the compositions and weights of the raw materials, ranged from 4 to 6% Cr and from 44 to 50% Ni. The alloys also contained approximately 0.02% Al, 0.06% Si, 0.15% Mn, 0.05% C, the remainder being iron.

The stress developing below about 880° F. in all cases passes through a minimum, then through a maximum, and in some cases, through a second minimum. The more pronounced minimum and maximum stresses at about 750° F. and 550 to 700° F. are caused, respectively, by the transformation in

(Continued on p. 560)



These steel "legs" for giant B-36 bombers are believed to be the largest die forgings ever produced in the 4300 series of nickel alloy steels. Manufacturer is the Cleveland Pneumatic Tool Co., a leading producer of landing gear for commercial and military aircraft.

180-POUND INCONEL FURNACE FIXTURES CARRY 3500-POUND FORGINGS

What are believed to be the largest die forgings ever made of the 4300 series nickel alloy steels are being produced by Cleveland Pneumatic Tool Company, Cleveland, Ohio, for use in the landing gear of the Air Force's immense B-36 heavy bomber.

Since they weigh from 1500 to 3500 pounds each, handling these forgings during heat treatment posed a tough problem.

The treatment necessary was: 8 hours at a maximum of 1700°F. and air cooling; 8 hours at a maximum of 1500-1600°F. and oil quenching; and finally, tempering at 1000°F.

A suspension fixture was wanted that could carry the forging through the entire normalize-quench-temper cycle. But it had to be absolutely dependable. If it should fail in the furnace, dropping 3500 pounds of dead weight to the furnace floor, either the forging or the furnace or both could suffer extensive damage. At the very least, the job of removing 3500 pounds of red-hot metal would be tough.

Cleveland Pneumatic recalled their past experience with Inconel® furnace equipment. Then they made a study of Inconel's high-temperature characteristics, noting particularly such properties as its 1000-hour stress-to-rupture strength at 1600°F. of 2700 psi. It looked as though Inconel would do the trick, if the proper design could be worked out.

Their engineers designed a fixture that seemed practical, and they asked Ohio Iron Works Company of Cleveland to fabricate three fixtures from the design. These were made from 3 and 4-inch diameter Inconel rod and 1-inch Inconel plate. One-inch holes were drilled in the rods, to lighten the fixtures.

When completed, each Inconel fixture weighed 180 pounds—slightly more than 1/20th the weight of the forgings they carry.

They have been in steady use for 10 months now, and still show no sign of wear.

The reasons why Inconel gives such excellent service are not hard to find. Its rugged strength at red heat, coupled with strong resistance to sulfur-free furnace atmospheres, make Inconel one of the real high-temperature "workhorses" in use today.

If you, like the Cleveland Pneumatic Tool Company, have a high-temperature metal problem, either for immediate defense requirements or for future installations, you are invited to ask the help of INCO's Technical Service Section. They will be glad to furnish recommendations.

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Metal-to-Glass Seal

(Starts on p. 556)

the glass contraction curve and the inflexion in the metal contraction curve at its Curie temperature.

The work clearly proves that the stresses in seals made with nickel-chromium-iron alloys and standard lead glass can be maintained at low values at all temperatures by carefully controlled alloy composition. A suitable composition contained 47% Ni, 5% Cr. An excellent match was obtained even though the alloy Curie temperature was approximately 650° F. and the glass transformation temperature was 750° F. Melts of this alloy made on a 100-lb. production scale have proved conclusively that it can be made satisfactorily on a commercial basis. Results prove that the new alloy is an outstandingly good match to lead glass at all temperatures, and the ease with which seals of both wire and sheet alloy have been made to lead glass in practice bear out this conclusion. TOM BISHOP

Vibration of Liquid Mg-Al Alloys*

ORDINARY magnesium-aluminum alloys crystallize in a manner remote from equilibrium. While the primary crystals alone should form during slow freezing up to a concentration of 13% Al, a secondary phase appears in alloys containing considerably less aluminum, and instead of being part of a eutectic, it forms a separate phase, which the Germans call a degenerated eutectic.

Siebers and Bulian subjected a number of magnesium-aluminum alloys to ultrasonic treatments at 280 kilohertz and found that the secondary phase neither disappeared nor decreased in amount, but acquired a eutectic type of crystallization, with islands of the primary phase in it. They found also that vibrations of a purely mechanical kind, of the order of 50 hertz only, had the same effect. And in both cases the new eutectic resisted complete homogenization just as stubbornly as the type ordinarily obtainable.

M. G. CORSON

*Abstract from "The Effect of Sonic and Ultrasonic Vibrations on the Structure of Magnesium-Aluminum Alloys With 4 to 12% Al", by Charlotte Siebers and Walter Bulian, *Metallforschung*, Vol. 1, 1946, p. 158-160.

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Effect of Repeated Machine Welding*

In a brief study made by Babcock and Wilcox Co. for the Atomic Energy Commission, some information was obtained relative to the effect of repeated machine welding on firebox quality steel plate of A.S.T.M. SA-212, Grade B type. Welding was performed with the submerged-arc process using d.c. reverse polarity in a ½-in. deep groove machined in 2-in. thick plate. The groove cross section was trapezoidal with a top width of 1½ in. and a root width of ½ in. Weld metal was deposited by means of a modified split-pass technique, about 17 individual passes being required to fill the groove. Runout tabs were attached at each end of the test piece to accommodate the starting and stopping of the arc at the beginning and end of each pass.

When the first weld was completed about one quarter of the length of the test plate was cut off and the weld in the remaining three-quarter length was machined out to the original groove cross section for the second weld. This procedure was repeated three times so that there were four quarter sections of the original test plate length in which the first section had the original weld, the second section one reweld, the third section two rewelds and the fourth section three rewelds. After polishing and etching a cross section of each of these four weld sections, the microstructures of the welds, the heat-affected zones and the parent metal were examined at 100×.

According to the report, the photomicrographs are typical of the structures found in all the repeated welds; however, it was observed that more areas in the heat-affected zones were found to have a smaller grain size as the number of welds increased. Such areas were a part of the previous deposits which were not completely removed by the succeeding repeat weld. This reviewer noted that photomicrographs of regions immediately adjacent to the weld deposit in the heat-affected zone of the base metal indicate a noticeable grain coarsening as the number of repeat welds increased.

The coarsening of the grain ad-

(Continued on p. 564)

*Abstracted from "Effect of Repeated Welding on the Physical and Metallurgical Properties of A-212 Plate", Report No. 3363, Babcock and Wilcox Co., A.E.C. No. NP-1700.

Effect of Repeated Machine Welding

(Continued from p. 562)

jacent to the weld metal did not exhibit any detrimental effect on either hardness or tensile strength of the welded joint; bend tests showed no adverse effect on ductility due to rewelding. To obtain information regarding the temperature gradient in the base metal adjacent to the groove during welding, four thermocouples were embedded in the test plate by drilling holes from the back of the test plate to a depth of 1 in. One hole was located so that the bottom was ¼ in. from the machined face of the groove and succeeding holes were located successively ⅛ in. further away from the groove and spaced ½ in. apart lengthwise of the weld. In this manner the maximum temperature during welding was determined at four points removed from the line of fusion (bond) by successive distances of ⅛ in.

Charpy keyhole test bars were taken in groups of three at three levels below the top surface of the plate. Levels at which these were taken were ⅜, 11/16 and 1½ in. as well as at four locations on each level. The first impact area, or center of the notch, was within the heat-affected zone which had been subjected to microstructural changes during each repeated weld. The second and third impact areas were just outside the heat-affected zone at temperatures between 1300 and 900° F. in a region of no microstructural changes as observed on previous investigation. The fourth series of impact tests was taken in unaffected base metal at the lower level of the temperature curve, around 650° F.

Similar trends of impact strength appeared at all the levels tested. A high impact value (27 to 31 ft-lb.) was found for the heat-affected area, and a minimum impact value (22 to 23 ft-lb.) for the area just outside the weld heat-affected base metal. In areas further removed from the affected zone the impact strength increased to values approximating that of the plate material (22 to 26 ft-lb.).

Apparently this trend is not affected by the rewelding, and the impact properties obtained in and adjacent to the heat-affected zone showed satisfactory values and no trend was found to indicate that the base metal in this area has been appreciably affected.

William L. Warner

Tool Steel Topics

BETHLEHEM STEEL

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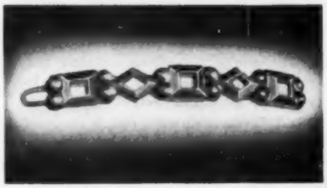

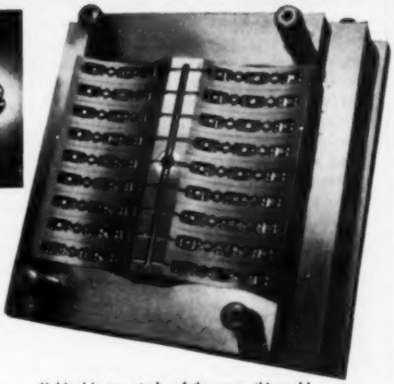

Hobbed in one stroke of the press, this mold is a fine example of intricate detail. Made from Duramold A, it produces injection-molded barrettes.

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Booklet 271 contains details on properties, heat-treatment, and applications of Bethlehem tool steels for plastic molding. It will help you select the right tool steel for hobbed molds, machine-cut molds, and master hobs. It's yours for the asking. Address your request to our Publications Department, Room 1041, Bethlehem, Pa.

Our Tool Steel Engineer Says:

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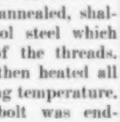
Basing his facts on investigations of several thousand tool failures, one of our tool-steel engineers has written a practical discussion which should help every user of tools to increase his batting average. Entitled *Tool Failures and Their Cure*, the first portion deals with mechanical causes of failures, such as poor tool design, improper grinding, and many other factors.

Problems dealing with faulty heat-treatment and distortion are also described in some detail. The author tells how to make good tools and offers many practical suggestions to avoid the troubles usually encountered in toolmaking.

Added interest is provided by a number of photographs which illustrate various types of failures. Originally published in installments by *Metal Progress*, this helpful treatise is now available in reprint form. Address your request to our Publications Department, Room 1041, Bethlehem, Pa.



Bethlehem ULTRASONIC TESTED **Tool Steel**

MgO-TiN-NiO Cermets*

USUALLY, metals do not wet ceramic oxides so that many cermet bodies are only mechanically bonded, whereas a chemical bond is essential for obtaining high strength. In most cermet work the metal powders are permitted to oxidize slightly to provide a metal oxide surface which is more compatible with the ceramic particles than are the metal surfaces. In the present approach, metalloids such as nitrides, carbides, borides, and hydrides were considered as a source of an intermediate phase which could be compatible with both the metal and oxide and, in addition, would promote interaction of these two phases.

Titanium nitride was selected for the study on the basis of its atomic structure and lattice size in comparison to those of the metal and oxide. Ten points in the ternary diagram were selected for study with the MgO ranging from 50 to 80%, the TiN from 40 to 10%, and the NiO from 10 to 40%. The best body found in the preliminary work is composed of 50% MgO, 30% TiN, and 20% NiO. Nickel oxide was used because the nickel metal powder caused distribution difficulties.

To prepare the test bodies a solid solution of magnesium oxide – nickel oxide was prepared by firing disks of the mix at 2550° F. for six hours, crushing and grinding, mixing this with titanium nitride, followed by pressing the material at 60,000 psi. into a ¾-in. diameter bar 5 in. long. Eight test specimens were then cut from each bar. Final pieces were fired in an argon atmosphere induction furnace to 2900° F. in 1½ hr. plus ½ hr. at temperature.

Tests on fired specimens of the body included: Transverse strength, shrinkage, bulk density, thermal shock resistance and oxidation effects on the transverse strength. The shrinkage was 10%, absorption was 0.228%, bulk density was 4.21 g. per cc., gain in weight during firing was 0.45%, and original modulus of rupture was 23,200 psi. at room temperature. Modulus *(Cont. on p. 568)*

*Extracts from "High Temperature Bodies in the System MgO-TiN-NiO", by L. D. Hower, a paper given before the Refractories Division at the annual convention of the American Ceramic Society, April 1950.

MgO-TiN-NiO Cermets

(Starts on p. 566) of rupture values were also obtained at 1500, 1800, 2000, 2200 and 2400° F. They showed a decrease in strength at 1500 and 1800° F. of approximately 3000 psi. from the room temperature value; at 2000, 2200, 2400° F. the values increased 7000 to 10,000 psi. over the room temperature value.

Measurement of the modulus of rupture after subjecting test bars to the oxidizing atmosphere of a gas-fired furnace at 2000° F. for 3, 6, 12, 18 and 24 hr. showed an increase of 50% over the previous values after only 3 hr. of oxidation. This gain in strength remained constant for the full period of the oxidizing treatment. Two other compositions were also included in this test. The best of these two contained 40% MgO, 44% TiN, and 16% NiO and showed an over-all greater strength than the previously described body. Petrographic studies of the specimens indicated three zones of oxidation which were most pronounced at the corners. The inner portion was the unaffected body. The outer layer appeared to be devoid of nickel metal and showed no yellow color of titanium nitride or titanium oxide which indicated that titanium dioxide had probably been formed. The middle layer still contained nickel but no titanium oxide or titanium nitride. After subjecting the specimens to thermal shock, modulus of rupture tests showed a decrease in strength in proportion to the number of thermal shock cycles.

The test values reported are considered as only a general indication of the properties of these bodies.

LOUIS R. MCCREIGHT

Welding and Stress-Corrosion Cracking*

FAILURES in welded mild steel structures used for conveying crude coal and coke oven gas during recent years and the various investigations resulting therefrom have focused the attention of the British

(Continued on p. 570)

*Abstracted from "Stress-Corrosion Cracking in Welded Steel Structures", by C. E. Pearson and R. N. Parkins, *Welding Research*, Vol. 3, December 1949.

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Welding and Stress-Corrosion Cracking

(Continued from p. 568)

Welding Research Association on the problem of stress-corrosion cracking in welded steel structures.

This study involves a failure in a welded steel gas main carrying saturated crude coke oven gas at 95 to 105° F. The pipe was fabricated from $\frac{3}{16}$-in. thick mild steel plate of basic bessemer quality (0.05% C) and welded longitudinally into sections so that seven sections were joined by circumferential welds to make a 32-ft. 6-in. length, the ends of which were flanged for bolted connections to adjacent lengths. After about six months service, serious cracking developed in the vicinity of the circumferential welds and continued to progressively develop during the ensuing 18 months at which time the main was dismantled. These cracks were roughly parallel to the weld, only occasionally crossing the weld, and in many instances were as much as 1 in. away from the weld. Occasional short longitudinal and transverse cracks were found in the longitudinal welds. Micro-examination indicated that the cracks originated at the inside surface of the pipe wall and followed an intergranular path through the steel. The steel had a normal number of nonmetallic inclusions and showed intergranular areas of cementite.

Due to the time factor involved in studying this problem of stress-corrosion cracking, the difficulty of conducting field service tests is apparent. This situation points to the basic need for an accelerated short-time laboratory test procedure. In order that such a test procedure be effective a correlation between parallel field and laboratory tests is considered necessary. For this reason a field test was conducted at the plant where the original failure occurred using two bessemer and four openhearth steels of 0.07 to 0.22% C to fabricate a composite bend which was installed in the gas main. This welded bend remained in operation for a period of two years before removal for examination. In the interim, butt welded samples of these six steels were tested in the laboratory by immersion in a boiling nitrate solution (60% calcium nitrate and 3% ammonium nitrate) for a period of 250 hr.

(Continued on p. 572)

Welding and Stress-Corrosion Cracking

(Starts on p. 568)

Micro-examination of samples from the composite bend and a tabulation of cracking tendency, using as a cracking index of the steels the number of cracks per 100-mm. length of specimen edge examined, gave an order of rating of the steels which agreed with the rating obtained from the laboratory tests in the boiling nitrate solution. Because the results indicated a good correlation between the two methods of test, they were considered to reasonably justify using the boiling nitrate test for subsequent work on the problem of stress-corrosion cracking.

A series of three bessemer and fifteen openhearth steels of 0.07 to 0.27% C were used in tests of welded specimens of three types with the boiling nitrate solution. One type of specimen was a simple butt welded plate $\frac{3}{16}$ x 10 x 12 in. with the weld through the center of the 10-in. dimension using a 70° single "V". A second type of specimen was a $\frac{3}{16}$ x 10 x 20-in. plate to one face of which a patch plate $\frac{3}{16}$ x 2 x 10 in. of the same steel was attached by a single-pass fillet weld. The third type of specimen was a $\frac{3}{16}$ x 10 x 12-in. plate cold rolled to a 24-in. diameter arc after which two parallel weld beads were deposited circumferentially on the convex face near the middle of the plate. The plate in all specimens was as-rolled when tested.

These three types of specimen were selected to obtain different residual stress patterns for the corrosion test. In the flat butt welded specimen the principal stresses are parallel to the weld and symmetrical about it and are of yield point magnitude in tension adjacent to the weld. In the patch plate the stresses form more of a biaxial pattern since those stresses transverse to the weld approach the yield point magnitude of the longitudinal stresses. Due to the rolling of the plate in the third type, rigidity of the specimen transverse to the welds is enhanced and as a result the maximum stresses are transverse to the weld rather than longitudinal.

The orientation of the cracks developed after 200 hr. in the nitrate solution shows that the major axis of the crack lies perpendicular to the direction of principal tension stress. Cracks originated indiscrim-

(Continued on p. 574)

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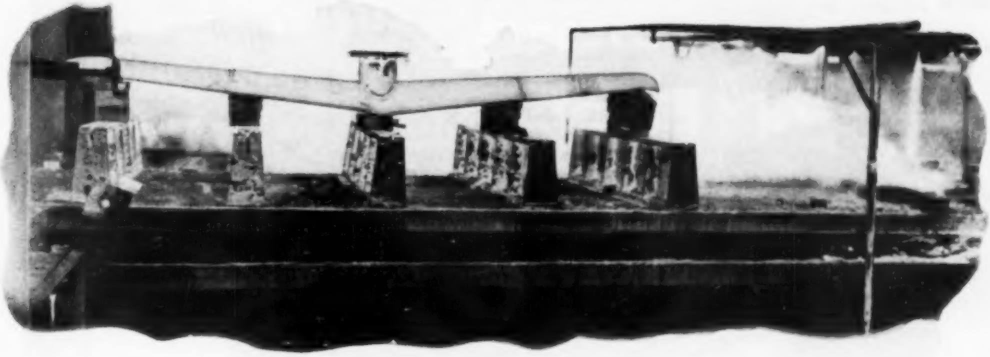

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Welding and Stress-Corrosion Cracking

(Continued from p. 572)

inately in weld and plate metal alike and weld metal discontinuities were invariably associated with a crack. By rating the steels on the basis of number of macrocracks observed it was found possible to divide them into three groups: *(a)* Those with a high cracking tendency, *(b)* an intermediate group of moderate susceptibility, and *(c)* a group highly resistant to nitrate cracking.

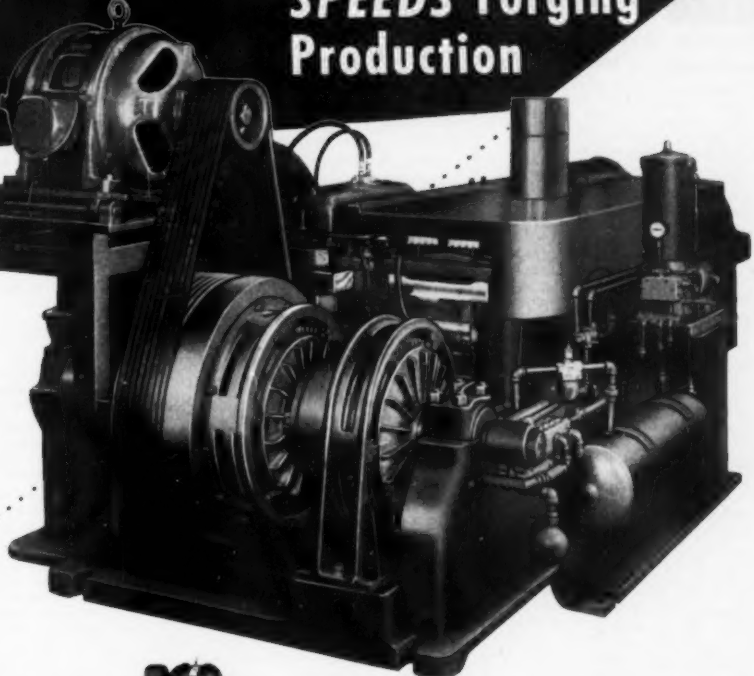
The most susceptible steels were those of low carbon while those of the highest carbon range were least susceptible. The intermediate carbon steels were in the intermediate group. The effect of deoxidation treatment was not demonstrated clearly because of variation in carbon content and there did not appear to be any beneficial effect from killing with aluminum. It appeared quite evident that cold working before welding increases the susceptibility to intergranular cracking in the nitrate test. Also, the ferritic-type weld metal is indicated as susceptible to intergranular cracking since tests with austenitic weld metals show that the cracking is confined to the plate metal entirely in those instances. In addition, the cracks did not grow to the same extent as occurred with the ferritic weld metals.

The influence of degree of stressing, or stress level, on intergranular cracking susceptibility has been investigated and is considered to offer a good method of comparison of steels. In the present work the plate specimens were not welded but were tested with stress imposed by a restraining jig which subjected strip specimens to four-point loading in bending. Surface scale and irregularities were removed by grinding prior to testing. The time required for initial crack formation rather than the number of cracks formed in a specific time interval was used as a criterion of susceptibility at a particular stress level. The results indicate that, as the stress level is reduced, the time for cracking to appear (in the nitrate test) becomes progressively longer until a minimum stress level is reached below which a very extended period of time is required to form cracks.

It was found that the majority of as-rolled steels did not crack under

(Continued on p. 576)

Do You Know? Acme XN Cushion Drive *SPEEDS* Forging Production



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Welding and Stress-Corrosion Cracking

(Continued from p. 574)

the simple bending stress imposed by the jig, in spite of the fact that the stress so applied often exceeded the principal stresses known to exist after welding. Most of the steels were rendered crack-prone by cold working before testing, the cold work being applied by elongating the strips 10% in a tension testing machine. This result would appear to indicate that conditions resulting from welding are more conducive to intergranular cracking than those which can be produced by simple bending in the jig. The difference may be associated with the biaxial stress pattern present in welded structures or the heat effect of welding or both. However, the order of rating the steels as to cracking susceptibility in simple bending in the jig is similar to that found from tests of welded plates of the three types previously discussed.

Experiments with imposing anodic and cathodic potentials on strip specimens of the 0.07% carbon steel held in the jig with a maximum bending stress of 38,000 psi. while immersed in the nitrate solution indicated that the tendency for intergranular cracking is markedly increased by applying a potential of low current density. In no case was any cracking observed in the specimen when it formed the cathode.

With no current imposed, cracks appeared in about 15 hr. whereas with a current of 40 milliamperes per sq.in., extensive cracking developed in the anode in 1½ hr. With 100 milliamperes per sq.in., cracks appeared in one hour and with 200 milliamperes per sq.in. they appeared after only 30 min. immersion. Also, cracking is much more extensive when the anodic potential is present. These results suggest that the mechanism of stress-corrosion cracking is electrochemical in nature.

In order to determine the effect of a low temperature postheat treatment of welds on intergranular cracking susceptibility, a series of butt weld test plates was heated at various temperatures from 392 to 698° F. for one hour and air cooled. After prolonged immersion in the boiling nitrate solution, the results indicated a decreasing crack susceptibility with increasing heat

(Continued on p. 578)

Welding and Stress-Corrosion Cracking

(Starts on p. 568)

treatment temperature. Also they suggest that a temperature of less than 572° F. would be effective for those steels which are less prone to crack.

Mechanical methods of relieving stress, such as peening, can be effective in reducing the intergranular cracking susceptibility of steel. Both shot-peening and hammer-peening, applied after welding and when the test plate had cooled to room temperature, were tested. Shot-peening was done with 3-mm. angular cast iron shot using an air pressure of 80 lb. per sq.in. Hammer-peening was performed with an electrically operated hammer using a hardened tool 3/16 in. in diameter with a head of ½ in. radius. This treatment was performed at a rate of the order of one minute per linear inch of weld over an area extending to 1 in. from either edge of the weld. The test plates were treated on both surfaces.

Results of the peening tests indicate complete immunity to intergranular corrosion cracking is afforded by this mechanical treatment, performed as previously described. No cracking developed, even in the butt welded 0.07% carbon steel plate which was immersed up to 1600 hr. However, subsequent tests of patch-plate specimens, hammer-peened in varying degrees by varying the indents per unit of surface area, indicate that excessive peening, which leads to a state of high compression stress in the peened surface, can be harmful.

In conclusion, it is stated that while cases of cracking of this type in mild steel occur under conditions of caustic embrittlement and from the action of certain nitrate solutions, the occurrence of such failures in steels used in coal distillation plants has not hitherto been recognized. The typical form of this cracking, together with the attendant conditions associated therewith, lends weight to the belief that this cracking is an important example of the stress-corrosion phenomenon.

From the results obtained in this investigation the authors have inferred that:

1. Mild steels of widely different character show a varying sus-

(Continued on p. 580)

Welding and Stress-Corrosion Cracking

(Continued from p. 578)

ceptibility and none are completely resistant in the welded condition.

2. A broad correlation exists between the failures in the service tests and the laboratory tests using the boiling nitrate solution.

3. Cold working prior to stressing seems to improve the resistance to stress-corrosion cracking.

4. Peening of proper extent can be effective in improving the resistance of the steel to stress-corrosion cracking.

Welding of Armor*

UNTIL 1939, the view was generally held that the high alloy steels used for armor were quite unsuitable for welding. Careful control of the critical cooling rate of material surrounding the weld was necessary in order to avoid formation of a brittle martensitic zone in the structure adjoining the weld. Early attempts at welding light armor with ferritic electrodes were unsuccessful because of serious cracking at relatively low temperatures. This cold cracking was usually confined to the heat-affected zone. Early in 1939 a promising experimental austenitic rod was made having a core wire consisting of 18% Cr and 8% Ni. However, the weld metal showed a tendency to hot crack following its deposition. The addition of 2 to 3% Mo to the welding rod reduced this tendency markedly. Reasons for the success of austenitic electrodes were believed to be their ductility, the absence of an allotropic transformation and the less drastic thermal effects due to the lower welding currents used.

Not all factors, particularly differences in the performance characteristics of austenitic electrodes used under similar conditions, were satisfactorily explained until Hopkin advanced his hydrogen theory. He held that hydrogen present in the arc atmosphere was dissociated to the atomic state and entered the weld metal at elevated temperatures where it was held in solution until

(Continued on p. 582)

*Abstract of "Developments in the Welding of Armor", by T. L. H. Butterfield, *The Welder*, Vol. 16, April-June 1947, p. 26-32.

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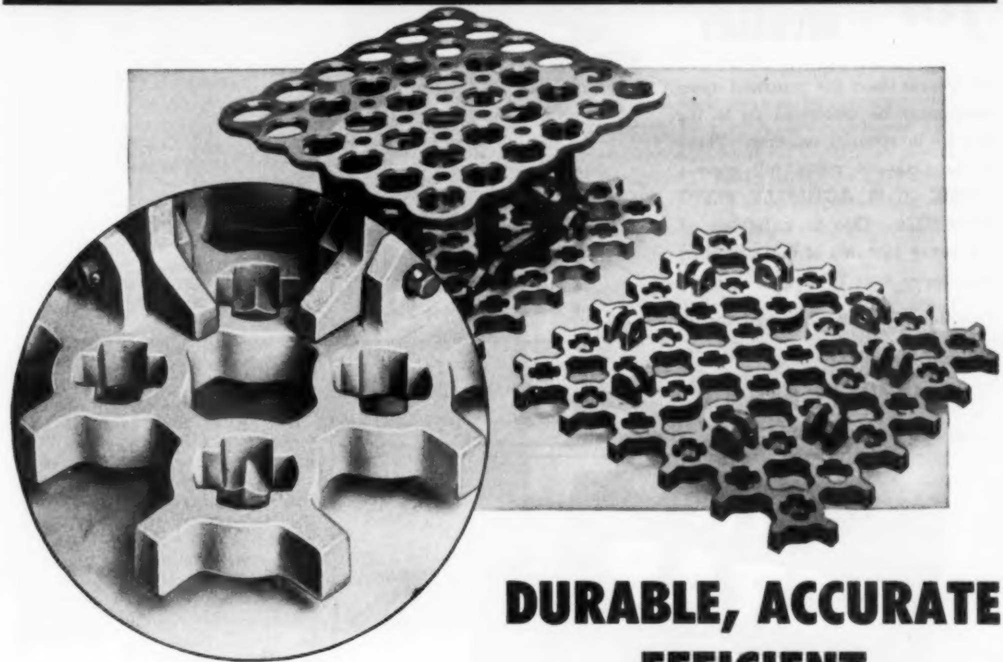

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Welding of Armor

(Continued from p. 580)

the allotropic transformation point was reached. At this point there is sudden reduction of the solubility of hydrogen. The hydrogen, now out of solution and in the atomic state, could diffuse through the lattice of the structure of the weld material into the hard zone where it produced cracking.

Two theories have been advanced to explain the mechanism of cracking: *(a)* Hydrogen re-forms as molecular hydrogen in the cavities or pores of the steel where it sets up high multiaxial stresses, and *(b)* hydrogen acts as an alloying element, stabilizing the austenitic phase in steel in conjunction with carbon and other elements. When transformation finally takes place at abnormally low temperatures, stresses are produced that lead to cracking. The hydrogen in the arc atmosphere results from substances in the electrode coating such as cellulose and moisture.

Carbon content has a marked influence on cold cracking, the maximum limit being 0.35% for austenitic welding rod. Above that value preheating and special techniques must be used. For given carbon contents the deep hardening steels are more susceptible to cold cracking than are the shallow hardening grades.

For welding of heavy armor the joint surfaces were precoated with 25% Cr, 20% Ni austenitic electrodes prior to infilling with 18% Cr, 8% Ni electrodes. Preheating the joints between 100 and 150° C. eliminates quenching effects. Normal multi-run techniques can be employed. Use of large gage electrodes ($\frac{5}{16}$ and $\frac{3}{8}$ in. diameter) improves weldability.

The tendency to hot crack with the use of austenitic electrodes is influenced by composition, electrode coating material, impurities and thermal conditions. The three distinct types of cracks noted were those that occurred above 800° C., in the region of 500° C. some time after solidification, and those forming below 370° C. Additions of manganese or molybdenum are beneficial in reducing hot cracking. Their effect is believed to be caused by the retention of islands of delta ferrite in the austenitic deposit. This delta ferrite has an affinity for the carbides precipitated during slow cooling thereby preventing their precipitation in the grain boundaries. HANS J. HEINE

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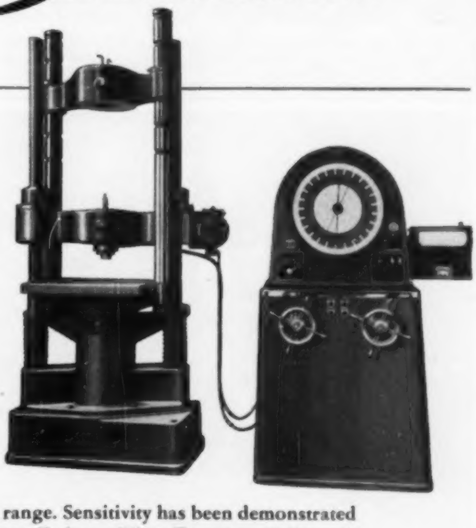

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Rolling of Powder Metals*

ATOMIZED iron powder has been rolled experimentally using powder of normal grain size, equivalent to minus 52-mesh British Standard Screen. Particle size was found to have a certain effect upon the optimum density for a given thickness; if the minus 300-mesh fraction was present, this factor was not of major importance. Three sizes of mills were employed in the investigation. The rolls of the smallest mill were approximately 3 in. diameter x 5 in. long, the intermediate size mill had 8-in. diameter rolls, and the largest were the 3-ft. diameter rolls of a two-high reversing mill.

All rolled strip made from metal powders was characterized by a variable degree of porosity that had an adverse effect upon physical properties. With the 3-in. diameter rolls operating at a single speed of 34 r.p.m., the regulating factor was the width of the rolling gap. Below a critical width at which the particles had become highly compacted, a considerably greater energy was required for producing a cold deformation of the strip. The densities of such strip were compared with the densities of thin pressings compacted in dies at known pressures and it was found that values of up to 89,600 psi. could easily be obtained in the small experimental mill.

Since the speed of the experimental mill was not variable, it was not possible to investigate the presumably highly important effect of rolling speed; tests on the 3-ft. mill did establish that a thicker strip having a tensile strength four to five times as great could be made at higher speeds. Beyond a certain limiting speed however, the strip did not form evenly owing to inadequate powder supply. The critical rolling speed depends, therefore, both upon the diameter of the rolls and the width of the rolling gap. Below a given rolling gap, the rolls were found to take automatically the exact quantity of iron powder required for a strip of uniform thickness and density.

Sintering of the compacted strip was done in hydrogen at between 1740° F. and 2200° F. as the strip was formed. Normally, sintering times of 1 to 3 hr. are required for ferrous compacts, but in view of the thinness of the strip and the need for employing very short sintering times to maintain a continuous process, a special study was made of the sintering process during the first 60 sec. Short strips 5 in. long and 0.8 in. wide were sintered under the time and temperature conditions mentioned, a tensile strength of 3500 psi. being obtained after 10 sec. at 2200° F. In further heating tests using direct current, the increases in tensile strength during the first second of sintering at 2200 and 2560° F. were determined. A value as high as 8960 psi. was obtained after 1 sec. at 2560° F.

The sintered strip requires further rolling. Hot rolling would be preferable, but difficulties arise in maintaining such thin material at the required temperature. Tensile strength and elongation increase with each pass. While three cold passes are sufficient for making strip with good tensile strength, at least five passes may be necessary if high elongation is required. The strip can be easily gas-carburized.

*Abstract from an article by G. Naesen and F. Zirm, *Stahl und Eisen*, Vol. 70, 1950, p. 995-1004.

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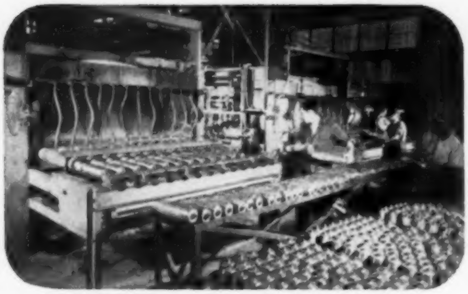

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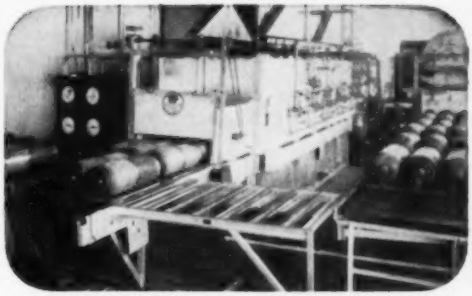

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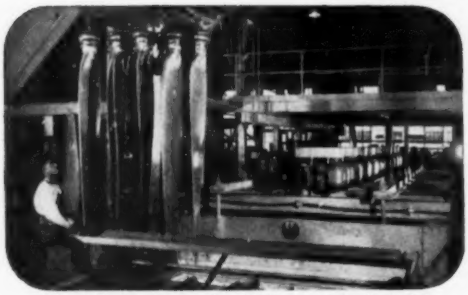

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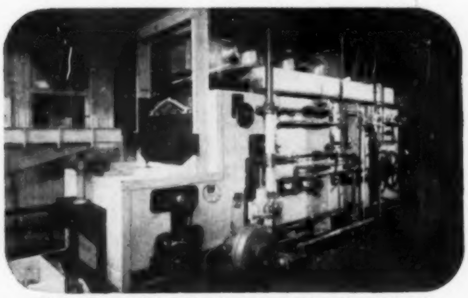

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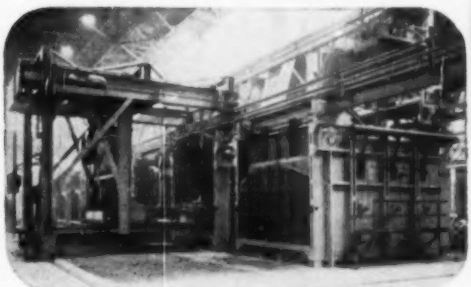

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